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16. Abstract (MAXIMUM 200 WORDS)

The benefits of the Marine Safety Programs of the U.S. Coast Guards can be estimated as the incident probability-weighted potential losses the regional and national economy would suffer due to the absence or failure of the programs. In this report, we analyze the economic impacts of two port shutdown scenarios on the Port Arthur/Beaumont MSA Region and the U.S. economy as a whole. The first, a Medium Consequence Scenario, is a four-day shipping disruption of Port of Beaumont due to the fuel oil spill from a tank ship accident. The second, a Complete Port Shutdown Scenario, is a total shutdown of both the ports at Port Arthur and Beaumont for 3 months.

This preliminary report outlines the Input-Output method developed to estimate these indirect economic losses. In addition to conventional aspects of economic consequence analysis, we also factor in resilience. This refers to the ability to mute the negative impacts of a breach in port security or safety by using remaining resources more efficiently and recovering more rapidly.

The report also outlines the key economic assumptions associated with the method and identifies the data needed to implement it. It then illustrates the methodology for the case of a complete shutdown of the ports in Port Arthur and in Beaumont, Texas.

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EXECUTIVE SUMMARY

The benefits of the Marine Safety Programs of the U.S. Coast Guards can be estimated as the incident probability-weighted potential losses the regional and national economy would suffer due to the absence or failure of the programs. In this report, we analyze the economic impacts of two port shutdown scenarios on the Port Arthur/Beaumont MSA Region and the U.S. economy as a whole. The first, a Medium Consequence Scenario, is a four-day shipping disruption of Port of Beaumont due to the fuel oil spill from a tank ship accident. The second, a Complete Port Shutdown Scenario, is a total shutdown of both the ports at Port Arthur and Beaumont for 3 months.

Medium term shutdowns of the Port of Beaumont and Port Arthur have potentially devastating economic consequences, especially to the Port Region (see ES-1). Annual losses in terms of gross output (sales revenue) in the Port Region can reach $452 million for the Medium Consequence Scenario and $12.7 billion for the Complete Port Shutdown Scenario, representing declines of 57.8% and 71.4% of baseline gross output for the periods of the disruption (4 days and 3 months, respectively). The impacts are so large primarily because the economy of the Port Region is so heavily dependent on imported goods, especially crude oil inputs for its refineries. If all possible resilience measures are fully implemented and successful, the output impacts in the Port Region can be reduced by nearly 80% in the Medium Consequence Scenario and nearly 70% in the Complete Port Shutdown Scenario.

Impacts are much larger in absolute terms, but much less in relative terms for the nation as a whole in both scenarios as compared to impacts in the Port Region. Output reductions for the Medium Consequence Scenario are $3.7 billion and for the Complete Port Shutdown Scenario are $164.9 billion, representing declines of only 1.2 % and 2.4% of baseline national gross output for the duration of the disruptions. The U.S. economy is much less dependent on imports into the Port Arthur/Beaumont than is the Port Region itself. This is also indicated by the very sizeable decreases in impacts at the national level due to resilience, which reduces the losses by more than 90% for the Medium Consequence Scenario and by nearly 95% for the Complete Port Shutdown Scenario. Still, the $8.5 billion residual loss for the Complete Port Shutdown Scenario is a large absolute amount despite the fact that it represents less than 0.1% of U.S economic output over a 3-month period.

Additional costs of port disruptions are presented in Table ES-2 for the environmental cost of an oil spill, the cost of shipping delays and the security value of using crude oil from the Strategic Petroleum Reserve. The sum of these additional costs is around $21 million. They are difficult to translate into output decreases both conceptually and empirically. For example, the value of the SPR security premium is a non-market value that does not translate into a cost or price increase. The cost of shipping delays can translate into price increases that decrease purchasing power and subsequently gross output. However, this calculation is beyond the scope of the model. The environmental impacts are stated in terms of reduction of commercial fishing and recreation, however, and do represent both direct and indirect output losses. Overall these miscellaneous costs are significant at the Port Region level, but trivial in the national context.

Table ES-1. Gross output impacts of port shutdown scenarios.

Scenario	Output Impact w/o Resilience		Output Impact w/ Resilience	
	Level (million 2008$)	Percent*	Level (million 2008$)	Percent*
Medium Consequence Scenario				
Port Region	452.2	57.8%	93.7	12.0%
U.S.	3,735.6	1.2%	342.4	0.1%
Complete Port Shutdown Scenario				
Port Region	12,729.4	71.4%	4,021.7	22.5%
U.S.	164,903.5	2.4%	8,506.1	0.1%

* The percentage impacts are with respect to the total regional or national output in the Port Shutdown period, i.e., 4 days for the Medium Consequence Scenario and 3 months for the Complete Port Shutdown Scenario.

Table ES-2. Miscellaneous costs.

Category	Cost (million 2008$)
Economic Costs of Oil Spill	1.2
Delay Costs of Shipping	4.0
Security Value of Oil Release from SPR	15.6
Total	20.8

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

BEA	Bureau of Economic Analysis
CBO	Congressional Budget Office
CG	Coast Guard
CGE	Computatable General Equilibrium
COPT	Captain Of The Port
CREATE	Center for Risk and Economic Analysis for Terrorist Events
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GICW	Gulf Intra-Coastal Waterway
GRP	Gross Regional Product
HAZUS	HAZards United States
HS	Harmonized System
IMPLAN	IMpact analysis for PLANning
I-O	Input-Output
MSA	Metropolitan Statistical Area
NAICS	North American Industrial Classification
REMI	Regional Economic Models, Inc
SC	Statistics Canada
SPR	Strategic Petroleum Reserve
USDOC	United States Department Of Commerce

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1 INTRODUCTION

The benefits of the U.S. Coast Guard Marine Safety Programs are the losses the programs prevent. Direct economic losses range from damage to a single ship and injury to its crew to shutdown of an entire port. In extreme cases, indirect economic losses can ripple along the supply chains of goods and services throughout the entire country.

This preliminary report outlines the method to be developed to estimate these indirect economic losses. In addition to conventional aspects of economic consequence analysis, we also factor in resilience. This refers to the ability to mute the negative impacts of a breach in port security or safety by using remaining resources more efficiently and recovering more rapidly.

The report also outlines the key economic assumptions associated with the method and identifies the data that will be needed to implement it. It then illustrates the methodology for the case of a complete shutdown of the ports in Port Arthur and in Beaumont, Texas.

1.1 U.S. Coast Guard Marine Safety Program

1.1.1 MISSION

The United States Coast Guard operates to minimize public risk in the maritime domain, either by preventing accidents and other adverse events from occurring in the first place, or by minimizing the consequences when they do. The Coast Guard Marine Safety program includes preventive measures such as the development of standards and regulations, the licensing of mariners, inspection of vessels under construction or in operation, or by clearly marking navigational routes. The Marine Safety Program always works to ensure the safety of tens of thousands of U.S. mariners, millions of passengers on ferries and other vessels, and tens of millions of recreational boaters. By preventing marine casualties, the Marine Safety program also protects the marine environment from oil spills and the introduction of other harmful substances, and strengthens the economy by minimizing property loss and disruptions to maritime commerce.

The Coast Guard Marine Safety program accomplishes this through a multi-faceted approach that includes standards development, mariner credentialing, compliance enforcement, investigations and casualty analysis, industry and public outreach, and international engagement.

1.1.2 PROGRAM SCOPE AND IMPACT

The Coast Guard Marine Safety program is responsible for minimizing risk to people and the maritime environment by ensuring the safe and environmentally sound operation of U.S. flagged vessels wherever they are in the world, and exercising Port State authority for foreign vessels operating in U.S. waters. The impact of the regulated industry is significant to the U.S. economy. For example, in 2008, United States deep-draft seaports and seaport-related firms employed over 8 million American citizens while adding nearly $2 trillion to our domestic economy. The Coast Guard is the lead federal agency with responsibility for operations within the nation's Marine Transportation System, which consists of 25,000 miles of inland, intra-coastal, and coastal waterways; encompasses 240 locks, 355 ports, 1,000 harbor channels, and 1,941

cargo terminals; and includes 18,000 bridges and 97,000 aids to navigation. The Marine Transportation System is how the majority of the nation's food, clothing and other finished products, oil, and other raw materials reach warehouses, stores, and gas tanks. More than $958 billion of international commerce—1.4 billion tons of cargo, including tens of millions of containers—are carried within this system. The Marine Safety program serves more than 8 million cruise ship and ferry passengers who log more than 65 million passenger-miles a year; and provide a venue for boaters who operate more than 12.8 million registered recreational vessels that generate an estimated 900,000 jobs and $100 billion in revenue. Additionally, the program supports military sealift program requirements for national defense.

1.1.3 MULTI-MISSION SYNERGY

The Coast Guard has added a variety of missions and authorities during its evolution as an organization, each building on prior successes. In the 1800s, Congress enacted legislation to create the Steamboat Inspection Service to protect the public from preventable marine incidents that were taking hundreds, and sometimes thousands, of lives. Preserving life in the aftermath of a marine incident was initially the responsibility of a separate federal search and rescue organization. These disparate agencies were deliberately combined over the years to become the modern Coast Guard in order to reap the synergistic benefits that unity of effort brings to these different responsibilities. This marriage of multi-mission responsibilities has created an interwoven fabric of prevention and response elements, the essence of risk management. The unique blending of these capabilities enables the Coast Guard to multitask and utilize the same resources to simultaneously accomplish several missions. This is particularly true in the Marine Safety program. When inspectors board vessels, they are multi-mission in their focus; while inspecting for safety, they also observe environmental protection and security conditions.

1.1.4 PROGRAM ELEMENTS

1.1.4.1 STANDARDS DEVELOPMENT

The Coast Guard's risk management role begins with development of a set of minimum safety standards that covers all aspects of marine safety, including ship design and construction, mariner qualification, lifesaving systems, and environmental protection. These standards help to influence mariner behavior that prevents maritime accidents. The Coast Guard is the primary federal agency for developing marine safety, security, and environmental protection standards and relies on a solid understanding of causal factors and risk management principles in the development of sound regulations. The Coast Guard also plays an active role in the development of industry and international marine safety standards, including the rules of major ship classification societies, standards organizations such as ASTM, and ISO as well as through the International Maritime Organization (IMO). The United States is an active member state of the IMO, and, through the Coast Guard, has maintained a strong leadership role since IMO inception in 1948.

1.1.4.2 MARINER CREDENTIALING

The Coast Guard Marine Safety program ensures the competency of the nation's mariners through its Mariner Licensing & Documentation program. The program issues licenses and documents to qualified mariners, and ensures their competency through a combination of training courses, requisite experience, and examinations. Because many foreign ships operate in U.S. waters, the Coast Guard works extensively through the IMO to develop and implement similar standards on an international level.

1.1.4.3 COMPLIANCE

The Coast Guard Marine Safety program systematically conducts inspections of U.S. and foreign vessels and marine facilities, and it reviews plans for vessel construction, alteration, equipment, and salvage to ensure safety and environmental protection standards are being met. These inspections are comprehensive in nature and often encompass machinery, electrical, piping, industrial, navigation, crew qualification, and pollution prevention systems. These inspections begin in the shipyard while the vessel is constructed, or in the factory where the lifesaving system is fabricated, and last the life of the vessel through periodic inspections. In a typical year, the Coast Guard Marine Safety program conducts more than 70,000 domestic vessel inspections, 10,000 port state control examinations, and performs reviews for more than 15,000 vessel plans for technical compliance. Additionally, the Coast Guard conducts annually 7,500 examinations and 7,000 boardings, either dockside or underway of un-inspected commercial vessels including fishing, towing, and passenger vessels.

1.1.4.4 RECREATIONAL BOATING SAFETY

The Coast Guard Marine Safety program acts to enhance boating safety by developing vessel construction and performance standards; and ensuring compliance through a robust program of factory inspections, visiting some 2,000 of the approximately 3,600 active recreational boat manufacturers each year. The Coast Guard promulgates safety equipment carriage requirements; and in partnership with state and local enforcement agencies, boards and examines more than 1.7 million recreational vessels each year. Additionally, the Coast Guard Auxiliary and United States Power Squadrons provide free vessel safety checks and inspections for more than an additional 130,000 vessels each year.

1.1.4.5 INVESTIGATIONS & CASUALTY ANALYSIS

For the period 1990 through 2007, the Coast Guard annually conducted an average of 14,000 incident investigations for reportable marine casualties involving vessels and facilities. The Coast Guard makes findings and lessons learned available to the public and other governmental entities, and uses the results of the investigations to develop new standards to prevent future accidents.

1.1.4.6 OUTREACH & INTERNATIONAL ENGAGEMENT

The Coast Guard Marine Safety program pursues education and outreach programs that stress *Prevention-Through-People*. The common theme in the safety literature is that human factors are the primary cause of most accidents. We proactively engage with industry stakeholders and associations; as well as with allied agencies at the local, state, and national level, to develop cooperative efforts to promote safe and environmentally sound practices. These efforts include partnerships with the Passenger Vessel Association, the American Waterways Operators, and the Cruise Line International Association aimed at creating a safety culture through non-regulatory means.

The Coast Guard also addresses safety through close working relationships with industry via the following federal advisory committees:

- Commercial Fishing Industry Vessel Safety Advisory Committee (CFIVSAC).
- Chemical Transportation Advisory Committee (CTAC).
- Great Lakes Pilotage Advisory Committee (GLPAC).
- Houston/Galveston Navigation Safety Advisory Committee (HOGANSAC).
- Lower Mississippi River Waterway Safety Advisory Committee (LMRWSAC).
- Merchant Marine Personnel Advisory Committee (MERPAC).

- National Maritime Security Advisory Committee (NMSAC).
- Navigational Safety Advisory Council (NAVSAC).
- National Boating Safety Advisory Council (NBSAC).
- National Offshore Safety Advisory Committee (NOSAC).
- Towing Safety Advisory Committee (TSAC).
- Delaware River and Bay Oil Spill Advisory Committee (DROBOSAC).
- Merchant Mariner Medical Advisory Committee (MMMAC) (proposed).

1.2 Marine Safety Unit Port Arthur, Texas

The Coast Guard created the Coast Guard Marine Safety Inspection Office (MIO) Port Arthur in 1942. It arose from the Coast Guard absorption of the Department of Commerce's Bureau of Marine Inspection and Navigation. In 1976, the MIO combined with the Captain of the Port (COTP) Sabine Pass, forming the Marine Safety Office (MSO) Port Arthur. Coast Guard Marine Safety Detachment (MSD) Lake Charles was established in 1976 as a sub-unit of then Marine Safety Office Port Arthur. In February 2001, the MSD was reorganized and established as Marine Safety Unit (MSU) Lake Charles. As a part of the Coast Guard's reorganization into Sectors, MSO Port Arthur became Marine Safety Unit Port Arthur in November 2005 under the command of Sector Houston-Galveston. Under the new Sector organization, MSU Lake Charles continues its longstanding and mutually beneficial relationship as a sub-unit of MSU Port Arthur.

The Commanding Officer of MSU Port Arthur is responsible for carrying out the Coast Guard's homeland security, marine safety, and marine environmental protection missions in a zone of responsibility that includes Southwest Louisiana and Southeast and East Texas. Included in this zone are the Ports of Lake Charles, Louisiana; Sabine, Port Arthur, Orange and Beaumont, Texas; 141 miles of the Gulf Intra coastal Waterway; and 4 Outer Continental Shelf Lease Zones.

Unit personnel inspect U.S. and foreign deep draft commercial vessels, offshore platforms, mobile offshore drilling units, and designated waterfront facilities. They monitor transfer operations involving hazardous materials, detect and respond to waterborne oil and chemical spills, and monitor clean-up operations. They also investigate vessel and personnel casualties and incidents of negligence attributable to licensed or documented Merchant Mariners.

Vessel Traffic Service (VTS) Port Arthur is a department at MSU Port Arthur and works for the Captain of the Port. The mission of the VTS is to monitor and enhance the safe and efficient movement of vessels within the VTS Port Arthur area in an effort to prevent collisions, rammings, groundings and the associated loss of life and damage to property and the environment. During a typical year, the VTS monitors over 51,000 vessel transits (total) within the VTS operating area. For the year 2008, the Ports of Beaumont and Port Arthur exceeded 100 million short tons of cargo and ranked 7th and 25th respectively, in total tonnage of U.S. ports based on U.S. Army Corps of Engineers data. Initiatives at the MSU include expanding VTS operational coverage to Lake Charles, Louisiana, while continuing to build and expand partnerships that enhance navigation safety and environmental stewardship.

2 ALTERNATIVE METHODOLOGY APPROACHES AND PRIOR STUDIES

Only a handful of studies have analyzed the total economic impacts of a disruption of marine operations, including port shutdowns (see the summary in Table 1 at the end of the text). The studies by Park et al. (2007, 2008) used an input-output (I-O) analysis approach to the problem. I-O is a static, linear model of all purchases and sales between sectors of an economy based on the technological relationships of production (Rose and Miernyk, 1989). It was developed by Nobel laureate Wassily Leontief and is the most widely used tool of economic impact analysis, primarily because it is straightforward and because I-O models are readily available at a low cost.

I-O models have their strengths and weaknesses. The former includes the accounting for all inputs (not just primary factors of production), multi-sector detail, capture of economic interdependence, and comprehensive inclusion of all market economic activity within a region or nation. Weaknesses include linearity, lack of behavioral content, and absence of the role of markets and prices. These weaknesses are less severe when I-O is applied to phenomena lasting only weeks to months, where major adjustments in responding to a crisis are relatively more limited.

Several other methods have been applied to port shutdowns. The INFORUM Model was used in a Congressional Budget Office study (CBO, 2006) of the disruption of container ships. INFORUM has at its core and I-O table but is conjoined with an econometric forecasting model. Econometrics refers to the combination of economic principles and specifically designed statistical techniques in the formal analysis of data. It is a data-intensive approach that typically requires a long time series to yield a forecasting capability. It is highly regarded, but has limitations because it only captures behavior of aggregate categories of economic activity and linkages. It is also limited because of its grounding solely in past history, thereby making it less amenable to capturing dramatic adjustments or shifts, unless relevant underlying considerations are built into the model structure.

A more limited econometric approach is exemplified by Chang's (2000) study of the economic impacts of the closing of the port of Kobe, Japan after the major earthquake struck its host region in 1995. The approach used a reduced form, single equation model rather than the integrated (simultaneous equation) model of multiple economic sectors and macroeconomic linkages of the larger macroeconometric modeling approach.

Another macroeconometric approach is the Regional Economic Models, Inc., Policy Insight Plus (PI^+) Model (REMI, 2010). This is a much more sophisticated model than INFORUM, in that it also incorporates features of marked clearing models based on more micro-level behavior, input substitution, and features of the new economic geography associated with regional competitiveness. CREATE researchers have applied this model, with a great deal of refinement, in a study of the shutdown of the U.S. economy to trade, tourism and immigration in the face of a potential terrorist attack or public health threat (Rose et al., 2009).

The final modeling approach is that of computable general equilibrium (CGE) analysis, considered by most to be the state of the art in economic impact analysis. CGE is a behavioral model of the interactions of individual producers and consumer categories responding to market price signals and within the constraints of labor, capital and natural resource availabilities (Rose, 1995). CGE models have their relative strengths and weaknesses as well. The former refers to the ability to maintain the relative advantages of I-O (I-O data are at its production core), while overcoming the many limitations by explicitly incorporating behavioral

assumptions, being inherently non-linear, and emphasizing the flexibility of the economy through a wide range of substitution possibilities. The weaknesses of CGE models are that many of its key parameters are borrowed from a range of sources (huge data needs do not allow for econometric estimation) and the assumption that the economy is always in equilibrium. CREATE has successfully modified a CGE model (to account for disequilibrium) and applied it to a border shutdown as well (Dixon et al., 2010).

An I-O modeling approach will be used as our major methodology to estimate the total economic impacts of disruptions of shipping and ports in this study. I-O was chosen because of its strong capabilities and the research team's ability to modify this approach to overcome some of its major limitations. Most of these refinements involve making the model more realistic and flexible. The majority of the modifications pertain to resilience, in this case the ability to mute the impacts of a major shipping or post disruption, both at the site and along the supply chain. Examples of resilience tactics include: diversion of ships to other ports, diversion of exports to substitute for constrained imports, substitution of inputs and conservation of inputs by port customers, use of inventories, and recapture of lost production after the threat is overcome. Interestingly, resilience has not been factored into many previous studies of maritime risks (see Table 2).[1]

There is a final reason for going with an I-O approach. REMI and CGE models are complex, and it is not easy for users of the model results to understand how the models work or arrive at their findings. Moreover, these approaches are very facile in their applications. Our approach will involve the modification of I-O methods to better reflect the set of linkages that result in macroeconomic impacts. This will consist of both demand-side and supply-side versions of the model, as well as the modification for resilience in various rounds of the computations. This recursive process will be done in stages enabling us to more clearly lay out the assumptions and macro linkages and to decompose the various aspects of the total economic impacts. In addition to making the analysis more accessible to the non-technical reader, it serves as a useful check on the estimation process.

3 SCENARIOS

In addition to calling for development of an economic impact model, the contract Scope of Work for this project calls for "Performing economic impact assessments on not more than two incidents originating at Port Arthur, TX. . ." We have chosen as one of these incidents the events that lead to a Complete Shutdown Scenario of the ports at Port Arthur and Beaumont. The Port of Beaumont is located upstream of Port Arthur; therefore, closing the port at Port Arthur resulting from any incidents will lead to the closing the port at Beaumont as well. The shutdown of the ports could occur through several means related to the failure of maritime inspections, including a ship or ships that explode in a strategic place in the harbor, or a ship that carries radiological or biological contaminants that are dispersed at critical points in the harbor. This scenario will provide an upper bound for all loss estimates for inspections failures in the Port Arthur/Beaumont Area. It will also provide the ultimate test of a methodology by simulating a large and long-lasting shock that affects not only the port region but the entire U.S. A 51-sector Port MSA Region I-O table (including Jefferson County, Orange County, and Hardin County) and a 51-sector U.S. I-O table are established to analyze the impacts of port shutdown to these two geographic areas. Appendix D presents the bridging table of IMPLAN 440 sectors and the 51 sectors in the I-O tables used in this study. The 51 sectors include the top 10 economic sectors in terms of gross output in the Port Region and 20 economic sectors corresponding to major imports shipped to the two Ports. The other IMPLAN sectors are aggregated into the remaining 21 sectors in our I-O tables.

The second scenario is a Medium Consequence Scenario stemming from a barge accident and consequent oil spill, which will only result in 4-day closure of the Neches River from the Port of Beaumont to the intersection of the Gulf Intracoastal Waterway at the Sabine River. Again, however, both ports are expected to be closed, but for a shorter time.

4 OVERVIEW OF THE MACROECONOMIC LINKAGES

Figure 1 displays the major linkages in the I-O model framework at five analytical time/stages of the scenario. The focus will be on the chain of economic causation for the example of a complete port shutdown.

The scenario begins with the Failure of Safety Inspection, which first translates into a risk of a port shutdown. At the Port Level, this leads to:

- Disruption of imports.
- Disruption of exports.
- Disruption of port onsite activities and operations.

Various resilience tactics will be implemented to mute impacts at the outset. Such responses would include: rerouting the traffic to other ports or to other transportation modes. They would also include the use of inventories by port customers and rescheduling of activities once the port reopens by working overtime or extra shifts.

The next stage is the Macroeconomic Level. Impacts stem from three aspects here as well:

- Intermediate goods shortfalls.
- Final goods shortfalls.
- Reduction in final demand associated with reduction in exports.

The first aspect will be estimated through the use of both the Supply-Driven and Demand-Driven I-O Model. The former captures impacts on customers down the supply chain, and the latter captures the impacts on suppliers up the supply chain. Both the Supply- and Demand-Driven I-O models are needed on the import side because, not only are the sectors using the imports as intermediate inputs and their successive rounds of customer sectors affected by the initial import disruption and the successive supply shortfalls, but the reduction in production of import using sectors also reduces the demand of the goods produced by successive rounds of upstream suppliers within the region or nation. Since the "final" (finished) goods shortfalls to end-users (consumers, government, and purchasers of capital equipment) do not generate any forward or backward linkage effects, they are simply added to the total macro effects directly. The last aspect, pertaining to shutdown of port operations preventing the shipments of exports, will be estimated by the use of the more conventional Demand-Driven I-O Model in terms of impacts on suppliers up the supply chain. There are a number of resilience tactics applicable here, and at other junctures of the analysis, which will be discussed in detail below.

Production of exports requires another perspective on the problem. This involves the use of the Demand-Driven I-O Model. Here, the disruption of port activity through the cessation of exports will reduce demand for inputs in their production. First-round suppliers will in turn reduce their demand, thereby starting a chain reaction of production activity decreases. The sum total of all of these impacts is a multiple of the original shock; hence, the term "multiplier effect" to characterize this process.

The Total Impact Level is depicted in the right-hand column of Figure 1. The total represents a summing up of all the various types of supply-side and demand-side impacts. Given the nature of the linear I-O model, all of these various boxes in Figure 1 are additive, and can be calculated and presented separately to identify the relative influence of the various and offsetting factors.

In the impact analysis of the two port shutdown scenarios presented in later sections, we organize the analysis for both the Port Region and the U.S. in the following structure:

1. Impacts of Import Disruption.
2. Impacts of Export Disruption.
3. Impact of Port On-site Operation and Activities Disruption.
4. Total Impacts (which are the sum of 1-3).

Moreover, the analysis will venture into the area of long-run effects. These could arise from permanent loss of business for the port due to now realized advantages of newly established logistical patterns, or from stigma that stems from real or imagined long lasting effects of a radiological or biological weapon.

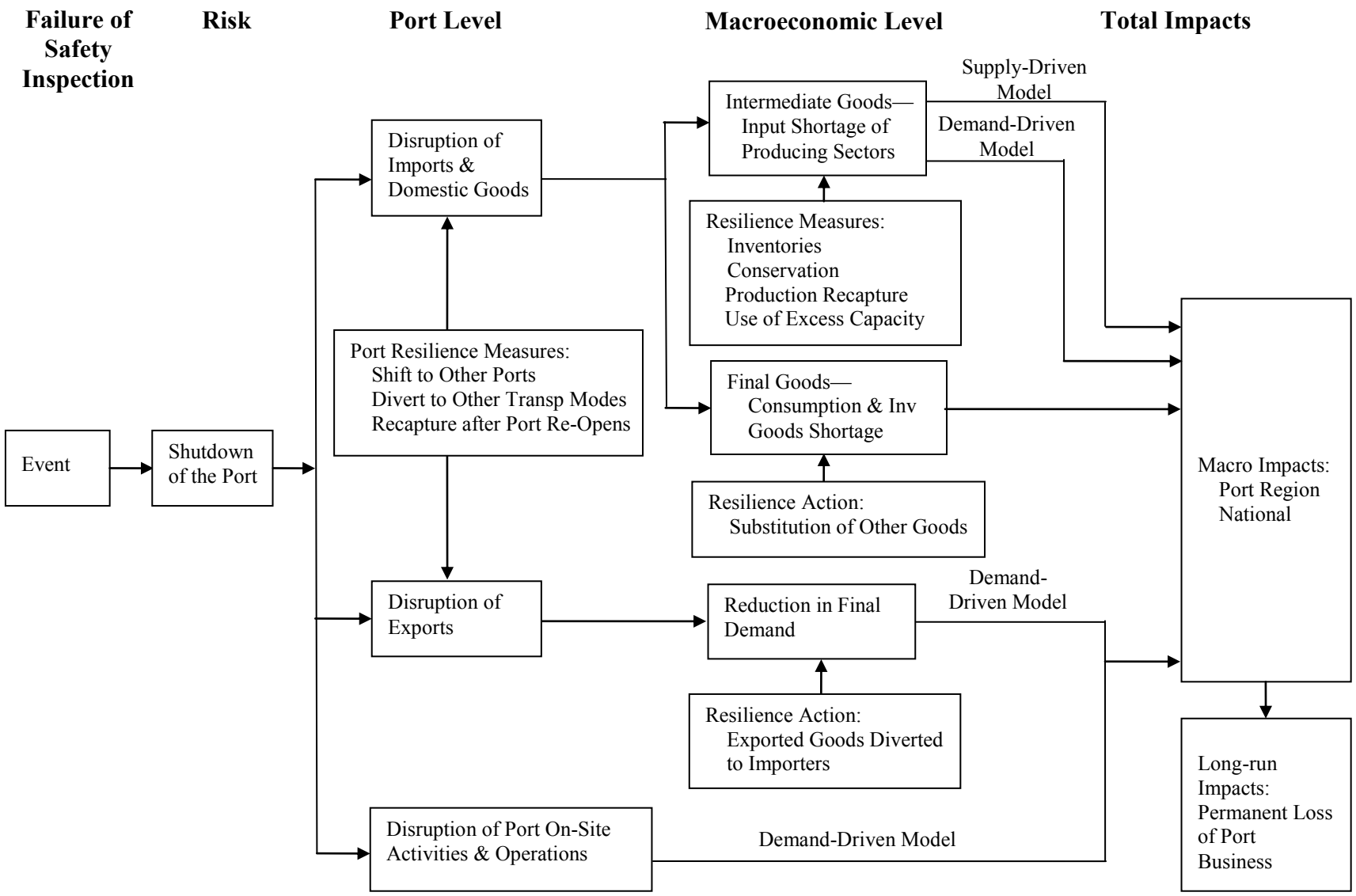


Figure 1. Estimating the total economic impacts of a port shutdown.

5 FORMAL I-O MODELING

5.1 Impact Analysis of Import Disruption

Import losses due to a partial or a complete port shutdown will cause disruption in intermediate goods that are used in domestic production. We use the supply-driven input-output approach to evaluate the impacts on the economic sectors that use the imported goods as intermediate inputs directly, as well as the indirect impacts to their successive rounds of customer sectors. A portion of imports are final (finished) goods that are purchased by domestic end-users (consumers and government), but these goods do not generate any supply-side impacts because they are at the end of the production chain.

We also estimate the demand-side impacts on the successive rounds of suppliers of the sectors whose production activities are affected due to the shortage of intermediate inputs. However, we do not consider the demand-side multiplier effects of the production of imported goods themselves (whether for intermediate or final use), because these goods are produced outside of the U.S.

1. Supply-Side Impacts of Import Disruption

The supply-side model interprets the basic flow I-O table in terms of marketing (or allocation) coefficients rather than production coefficients. That is, they reflect a fixed, proportional pattern of supplies of each good. Each column of the basic flow table shows the following relationship:

$$X_j = z_{1j} + z_{2j} + \cdots + z_{nj} + V_j \qquad (1)$$

In which, X_j is the gross output of sector j; z_{ij} is the intermediate input from sector i that is used in sector j; V_j is the sum of all of the elements in the payment section of column j, which include primary inputs such as labor, capital, and land, other value-added such as indirect business taxes. If we compute the supply-side allocation coefficient matrix A^s by dividing each element in the row by the row sum, we get $a_{ij}^s = z_{ij} / X_i$. Equation (1) is then can be written as:

$$X_j = \sum_i a_{ij}^s X_i + V_j \qquad (2)$$

In matrix form:

$$X = XA^s + V \qquad (3)$$

$$X = V(I - A^s)^{-1} \qquad (4)$$

When the changes in V, ΔV are known, the changes in gross output ΔX can be computed as:

$$\Delta X = \Delta V(1 - A^s)^{-1} \qquad (5)$$

A few steps needed to compute the vector of ΔV :

a. The port shutdown would result in import losses of many categories of commodities. The import commodity data are usually categorized by Harmonized System (HS) commodity codes. In the import disruption impact analysis, we will first convert the HS codes to the sectoral scheme of the I-O model. The disruption percentage of each import commodity is computed by dividing the amount imported through ports at Port Arthur and Beaumont by the total amount of this commodity that is imported from outside of the region and used in the regional production activities, i.e., for each commodity:
% Import Disruption = Import Coming Thru Port Arthur & Beaumont / Total Import

b. Based on the Industry Import Matrix of IMPLAN, which shows how each imported commodity is distributed to the producing sectors of the region, we figure out the major using sectors of these imported commodities. The criterion of determining the major users of a certain import can be that one sector uses more than 20% of the total amount of this imported commodity among all the producing sectors in the region.

c. For the same type of production input, many sectors purchase the commodity from both the local producers and from importers. If we assume that the same type of input has no difference in the producing process regardless of its source (locally produced or imported), the disruption percentage of a production input equals the import disruption percentage of this input (calculated in Step 1) times the percentage of this input that is imported from outside of the region:

% Input Disruption = % Import Disruption × % Input Imported

For example, if a sector uses $100 of input A, of which $40 is purchased from local producers and $60 is imported from outside of the region, the shutdown of ports at Port Arthur and Beaumont would result in a 50% reduction of the import of input A, and the percentage disruption of input A to the sector is 30% (50%×$60/$100)

d. According to the Leontief (fixed proportion) production function, X% reduction of one input in one sector would lead to X% reduction of output of this sector. Therefore, based on Steps 1 to 3, for each import commodity disruption, we can first compute the direct output reduction of the major using sectors of the import commodity.

e. Assume b_{jj}^{S} is the diagonal element of sector j in the Leontief inverse matrix of the allocation coefficient matrix (A^{s}),equation (5) can be rearranged to yield

$$\Delta V_j = \Delta X_j / b_{jj}^{S} \qquad (6)$$

After the computation of the output reduction of sector j (ΔX_j) in Step 4, ΔV_j can be computed by equation (6).

f. After getting ΔV , the total supply-side impacts ΔX associated with import losses can be computed using equation (5).

2. Demand-Side Impacts of Import Disruption

The output impact for the major import using sectors (ΔX_j) can be converted to a change in final demand (ΔY_j) of these sectors. This is calculated by dividing ΔX_j by the diagonal element b_{jj}^D in the Leontief inverse matrix of the demand-side coefficient table (A^D). After computing the final demand change vector of ΔY, the demand-side impacts of the reduced regional production activities due to the shortage of imported intermediate inputs can be estimated by:

$$\Delta X = (I - A^D)^{-1} \Delta Y \qquad (7)$$

The total output impact is the sum of the supply-side and demand-side total output losses. However, one last adjustment needs to be made because the same direct impacts (the direct output reduction of the major import using sectors) are included in both the supply-side and demand-side impact computations. To avoid double-counting, one of these direct impact vectors must be netted out.

5.2 Impact Analysis of Export Disruption

The shutdown of a port will also prevent the shipment of exports. Similar as the data on the import side, export data are also categorized by Harmonized System (HS) commodity codes. In the export disruption impact analysis, we will first convert the export commodity disruption data to a vector of final demand decrease (ΔY) of the corresponding sectors in the I-O model by using the bridging table between the HS codes and the sectoring scheme used in the I-O model. The final demand decrease of one sector will reduce its demand of intermediate inputs from its upstream suppliers, which in turn will affect successive rounds of suppliers up the supply-chain. The demand-driven I-O model shown in equation (7) will be used to compute the total impacts of export disruption to both the port region and the U.S.

5.3 Impact Analysis of Port On-site Operation and Activities Disruption

The daily operation of the port itself requires inputs like electricity, other fuels, technical services, food services etc. The disruption of the port operations will reduce the demand of goods and services from these sectors that support the port activities. The total impacts can again be captured by the demand-driven I-O model as shown in equation (7).

6 METHODOLOGY AND DATA FOR INCORPORATIING RESILIENCE

Several resilience options are available to entities affected by maritime disruptions. In the section, we identify them and explain in more detail how they will be modeled in the context of our input-output analysis framework.

Inventories of raw materials and finished goods used as inputs or intended for final customers through wholesale and retail markets can cushion the blow of a supply disruption. We make use of data from the BEA (2010) on inventories in our analysis (see Table A). Unfortunately, the data pertain to the total amount of inventories held by each producing sector but without reference to the type of input. We, therefore, assume that this percentage holds across the board for all material inputs into production for each sector.

We adjust the supply constraint by the amount of these inventories in terms of both a quantity and time dimension. That is, a given quantity of inventories is only half as effective if the disruption is twice as long as originally believed.

The ability to conserve on scarce materials (i.e., producing the same output but with fewer inputs) can reduce the shock as well. This represents the potential for a more careful use (less spillage, breakage, etc.) of these inputs. In the absence of other information, we assume a 2 percent ability to conserve for all material inputs. This has the effect of reducing the supply constraint for each good by this constant amount.

Excess capacity can help relieve the strain of a disruption by serving as a basis for providing local substitutes for inputs in some sectors. Excess capacity data are obtained from several sources such as the U.S. Department of Commerce (2006) and Federal Reserve (2006) (see the last column of Table B). They are applied to the disruption by lowering the input coefficient and raising the intra-regional, or intra-national, I-O coefficient for the good in question. This effectively lowers the disruption constraint for each relevant good.

Diversion of goods intended for export markets for use domestically is a potential resilient action. However, it is rare that exactly the same good simultaneously imported and exported from the same location, so this is likely to be minimal at the regional level. Note that we use a 51-sector I-O table in our analysis, but we use the full 440-sector IMPLAN I-O table information to make this adjustment, so we can avoid the "cross-hauling" possibility. Again, this adjustment comes in the form of a relaxation of the input disruption constraint.

Production recapture is the most effective means of resilience. It refers to the ability to recoup lost production after the crisis is over. Unlike a hurricane situation, where factories are damaged and may not be able to operate even when critical inputs become available, an ordinary port disruption allows for factories to turn their production lines back on immediately, and at a minimal cost of cleaning the system or overtime pay. We use the recapture factors from the Federal Emergency Management Agency's HAZUS loss estimation software (FEMA, 2009) adjusted for a time dimension in Table C as a scale or factor to adjust direct and indirect losses. That is, for a short duration of time (less than three months) most customers do not cancel their orders, but as the length of the disruption progresses, there is much greater potential for business in the affected region to lose market share. However, at the national level the potential for a decrease in the recapture factor is lower because it means losing business to foreign competitors, we must consider factors such as distance, unfamiliarity, uncertainty, and increased transportation costs. Thus, for the U.S. as a whole we adjust the recapture factors to decay at only half the rate of those at the regional level as presented in Table C.

Input substitution has the potential to alleviate the negative impacts of a supply disruption. However, information is rather scarce on this possibility. Moreover, this form of resilience is less operative for shorter periods. Finally, it is especially difficult to incorporate substitution into an I-O model. For these reasons, we have not included input substitution as a tangible form of resilience.[2]

Relocation is not an operative option within a region for supply disruption. Relocation need not be a physical move, but simply a shift in production from one plant to another within the same company. However, for a Port disruption at Port Arthur / Beaumont, the latter condition is limited, so we have omitted this type of resilience as well.[3]

7 PORT REGION OIL IMPORT DISRUPTION SIMULATIONS

To test our methodology, we performed a simulation of a 3-month disruption to crude oil imports from both non-U.S. and U.S. sources into the ports at Port Arthur and Beaumont.[4] Over the past several years, crude-oil imports have represented about 90 percent of all imports from foreign sources into the two Ports. Thus, the simulation of a disruption of this one type of good enabled us to focus our attention in the simulation, yet still being able to obtain an estimate of impacts close to the maximum possible for a 3-month period.

In the analysis, we simulated the various types of demand- and supply-side shocks noted in Figure 1. However, the analysis does not include any estimate of damage due to crude oil tankers themselves, nor any ecological damage that might ensue. Also, the analysis does not include impacts due to the disruption of port on-site operations and activities. The analysis was performed for the 3-county Port Arthur Metropolitan Statistical Area (MSA) at this time. Compared with the Port Region impacts, the impacts to the U.S. as a whole would be larger in absolute size. One reason is that not all of the oil imports coming into the two Ports are destined for refineries in the Region. In 2008, the total value of foreign crude oil import at the two Ports was about $29 billion. According to the IMPLAN Industry Import Matrix of the Port Region, the total foreign imported crude oil that is refined in the Port Region was about $13 billion. Therefore, we cap the total foreign crude oil import disruption to the Port Region at the total foreign import value indicated in the IMPLAN Import Matrix. The other reason that the total impacts to the U.S. as whole would be larger than the impacts to the Port Region is that when we do the impact analysis for the U.S. as a whole, there will be larger multiplier effects. Successive rounds of spending leak out of a small region like Port Arthur, because it is relatively dependent on other types of imports and exports for the rest of the economy. This is, of course, much less the case for the U.S. as a whole.

The foreign trade data are provided in the tables of Appendix E. The Port Region I-O table is presented in Appendix Table F1. The impact analysis calculations of the import oil disruption of the Base Case (with no resilience adjustments) are presented in Table 3. A summary of the results is presented in Table 4.

In the calculations, we estimated the impacts of a 3-month disruption of crude oil in the absence of any resilience. The crude oil input disruption of the major crude oil import using sector -- Petroleum Refineries -- sector is about 48.8%. This translates to a direct output loss of $4.3 billion for this sector. It results in total supply-side impacts of $4.7 billion and total demand-side impacts of $4.6 billion. However, there is double-counting of the direct output losses, which, when netted out, yield a total net set of impacts of $5.0 billion (an overall multiplier effect of 1.17 = $5.0B / $4.3B). This represents a reduction of 28.1 percent of economic activity in the Port Arthur/Beaumont MSA. The results are attributable to the very large role that petroleum refining plays in the Port Arthur MSA economy.

Next, we simulated five types of resilience individually, and then together:

- Re-routing of tankers carrying crude oil imports. For the 3-month period, we assume that 90% of the ships carrying imports would be diverted to alternative ports. However, we also assume that none of the re-routed crude oil will be transported back through pipelines to the Port Region. Therefore, re-routing does not mute the Port Region economic losses for the crude oil import disruption case.

- Release of crude oil supplies from the Strategic Petroleum Reserve (SPR). We assume that 4.16 million barrels of SPR (around 20% of the total SPR drawdown in the aftermath of Hurricane Katrina) will be released to the Port Region to ensure the minimum level operation of the key refineries in the region. The release of SPR can reduce the direct output losses to $3.9 billion, and total output losses to $4.5billion, or a reduction of 25.4 percent of baseline total gross output.
- Oil inventories. We assumed sufficient inventories to represent 12.2 percent of a 3-month raw materials supply to refineries. The use of inventory can reduce crude oil input disruption from 48.8% to 36.6%. However, the operation of the refineries also requires continuous re-supply of additives that are transported through an intermodal system under the normal circumstance. In the case that the Sabine-Neches Waterway is closed and the additives have to be transported by either rail or trucks, the refineries would have to reduce their production to around 60% of their operating capacity of normal conditions. Therefore, we simulate the direct output loss of the Petroleum Refineries sector as 40% even if the use of oil inventories can reduce the crude oil input disruption to 36.6%. This had the effect of reducing the overall impacts to $4.1 billion, or a reduction of 23.0 percent of total gross output in the region.
- We considered the diversion of crude oil export to be used by Port Arthur MSA refineries as well. The major crude oil export is domestic shipment from the Port of Beaumont to other regions in the U.S. However, compared with the value of crude oil imports, the exports are rather small — at about $405 million for the period in question. Gross output impacts are reduced to 24.7 percent of total gross output in the region.
- We assume the possibility of conservation of crude oil inputs at refineries at 2 percent. This had the effect of reducing total net losses to $4.9 billion, or an overall reduction of 27.5 percent in total gross output in the region.
- We also considered production rescheduling, which refers to the ability of businesses to make up (recapture) lost production at a later date. The recapture factors range from 15 to 49 percent, with the latter level being applicable to petroleum refining. Although refineries operate 24/7, there is excess capacity that would enable them to make up the lost production, though not necessarily within just three months. Total net impacts for this resilience adjustment result in total gross output losses of only $2.6 billion, or 14.6 percent of total economic activity in the region. Thus, this resilience adjustment is the most powerful of all, and practically cuts total losses in half.
- We combined all the resilience adjustments. Note, however, that they are not additive. Re-routing and release of SPR are applied first, followed by inventories and export diversions. However, the level of losses these resilience measures can mute is capped by the constraint of the additives. In other words, although the combination of SPR release, inventory use, and use of diverted exported crude oil has higher potential to reduce the crude oil input disruption, the maximum production capacity of the refineries is capped at 60% of their normal conditions because of the constraint in daily re-supply of additives needed in the petroleum refining process. Conservation is applicable after SPR release, inventories and export diversion are applied. Production rescheduling is applied directly to overall losses after all the other resilience adjustments have taken place. Thus, the total reduction from all resilience adjustments leads to output losses of $1.8 billion, or a reduction of only 10.0 percent of regional economic activity in the Port Arthur MSA. Thus, in our initial simulation, resilience has the potential to reduce the economic disruption of the curtailment of crude oil supplies to Port Arthur MSA by 64 percent.

8 ADJUSTMENT FOR SUPPLY-SIDE IMPACT DOUBLE-COUNTING

When we compute the supply-side impacts of multiple import commodity disruptions, there may be double-counting if one sector experiences input disruptions of more than one import commodity, or if one sector uses inputs that are produced along two different supply-chains of two import commodities. Figure 2 presents an example of the former case, and Figure 3 presents an example of the latter case. In Figure 2, imported commodities of Petroleum Refinery Products and Other Basic Organic Chemical Mfg Products are both production inputs of the Petrochemical Mfg sector. The impacts to the Petrochemical Mfg sector are not the sum of the impacts of the two disrupted inputs separately, rather the output impacts should be computed based on the more constrained input between the two. Figure 3 provides an example that double-counting may also happen in successive rounds of supply-chain effect calculations. In this example, imported commodities of Crude Oil and Other Basic Organic Chemical Mfg are production inputs of the Petroleum Refineries sector and the Other Chemical Mfg sector, respectively. The products of the latter two sectors are both production inputs of the Petrochemical Mfg sector. If we compute the supply-side impacts of Crude Oil disruption and Other Basic Organic Chemical Mfg disruption separately, and add the output losses of the Petrochemical Mfg sector computed from the two supply-side impact calculations together, there will be some double-counting. This is because both Petroleum Refineries and Other Chemical Mfg are both used as inputs in the production of the Petrochemical Mfg sector. Adding the impacts of shortages of these two inputs due to the supply-chain interruption of their production would amount to shutting down the Petrochemical Mfg sector twice.

The double-counting issue illustrated in Figures 2 and 3 can also be explained by the formal production function implied by the I-O model. The production function of the I-O model shows the relationship between the inputs and the output of a sector:

$$X_j = f(z_{1j,} z_{2j,} \cdots, z_{nj,} W_j)$$

where j represents sector j in the I-O table; $z_{1j,} z_{2j,} \cdots, z_{nj}$ represent the intermediate inputs (we assume that the inputs can be from either local producers or importers outside of the region); W_j represents the value-added.

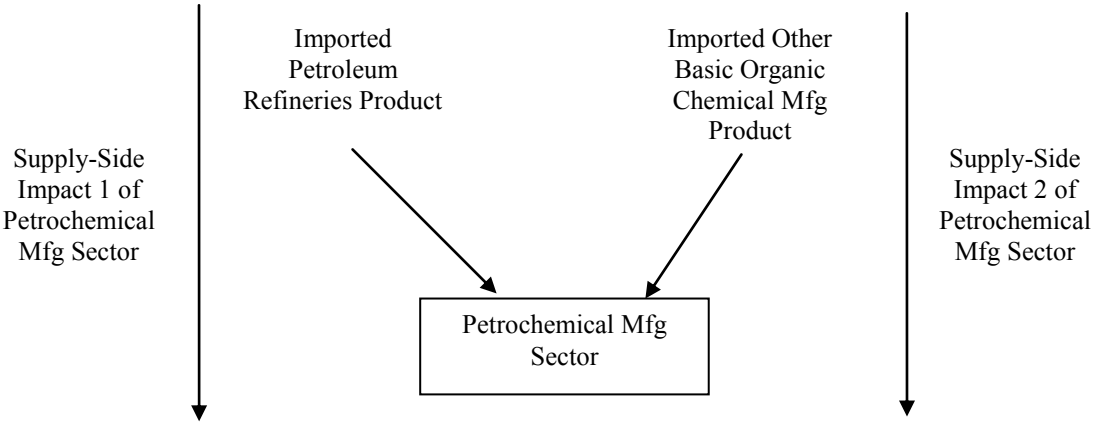


Figure 2. Double-counting of supply-side impact of the petrochemical mfg sector (two imported inputs disruption).

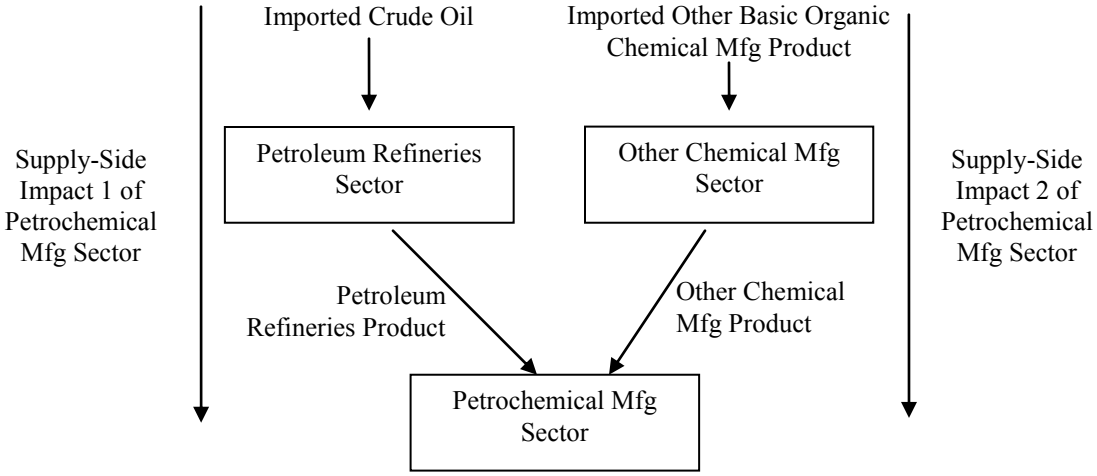


Figure 3. Double-counting of supply-side impact of the petrochemical mfg sector (two inputs disruption due to local production interruption).

The production function of the I-O model can be more explicitly written as:

$$X_j = \min\left(\frac{z_{1j}}{a_{1j}}, \frac{z_{2j}}{a_{2j}}, \cdots, \frac{z_{nj}}{a_{nj}}, \frac{W_j}{a_{wj}}\right)$$

where the "*a*"s are the technical coefficients.

The production function indicates that the loss in X_j (ΔX_j) equals X_j times the percentage decrease of the input that experiences the most significant disruption (i.e., the most constraining input). Having this basic concept of the I-O model in mind, when we compute the direct output losses of the sectors due to the disruptions of different imported inputs, we should not simply add the losses of input disruptions together before applying the supply-side calculation formula: $\Delta X = \Delta V(1 - A^s)^{-1}$. For each sector, we should only count the input disruption that represents the largest production constraint in percentage terms.

In the analysis, we will only make the double-counting adjustment at the level of direct output loss estimation resulting from the import disruption (such as the example shown in Figure 2). The analysis becomes complicated when we examine the potential double-counting in the successive rounds of supply-chain effects (such as the case presented in Figure 3). There are two major reasons we decide not to consider the double-counting in the higher orders of the supply-chain. First, we believe that the adjustment for double-counting at the direct output impact level would eliminate the majority of the double-counted effects. Second, based on the analysis presented in Appendix G, the pure supply-driven model tends to underestimate the loss impacts compared with the approach implied by the Leontief production function (Gruver, 1989). Though the supply-driven method we use in this study makes the adjustment in the direct loss estimation (i.e., we do not directly apply equation (5) to the value of import disruption, rather we compute the direct output losses of major import using sectors first as the direct effect), we do not make similar adjustments in the higher orders of the calculation. The potential underestimation of the supply-side loss impacts due to the use of the supply-driven I-O model and the potential overestimation of the loss impacts due to the double-counting that may exist at the higher orders of the supply-chain effects would offset each other to some extent.

9 IMPACT ON THE PORT REGION OF A COMPLETE PORT SHUTDOWN

In this section, we simulate the economic impacts of Scenario 1, a 3-month complete shutdown of the ports at Port Arthur and Beaumont, the Port MSA Region. The impacts of disruptions of imports, exports, and port on-site operations are analyzed separately.

Basic trade data of Port of Port Arthur and Port of Beaumont are presented in Appendix Tables E1 to E8. Appendix Tables E1 to E4 present the foreign import and export data for major commodities of the two Ports in Year 2008. The data source of the foreign trade data is WiserTrade Database. Appendix Tables E5 to E8 present the domestic import and export data for major commodities of the two Ports in Year 2008. The data source of the domestic trade data is Waterborne Commerce Statistics Center (WCSC). The WCSC data files only provide the trade data in short tons. In order to convert the short ton data into dollar values, we use the EIA price data of crude oil and some petroleum refinery goods. For other commodities, we use the WiserTrade data to compute the prices of the corresponding foreign imports or exports and use these prices to get the dollar values of those domestically traded commodities. Appendix Table E9 and E10 are the summary tables of imports and exports, respectively. In these two tables, the trade data of the two Ports are combined and commodities that fall into the same I-O model sector are aggregated together.

9.1 Impact Analysis of Import Disruption

1. Basic Case (without any resilience)

Based on the Industry Import Matrix of IMPLAN, which shows how each imported commodity is distributed to the producing sectors of the region, we ascertain the major using sectors of each import commodity. The criterion for determining the major users of a certain import is that one sector uses more than 10% of the total amount of this import that is consumed in the regional production activities. Table 5 calculates the percentage input disruption of the major import using sectors. The first column shows the disrupted import commodities due to the closure of the ports. The commodities have been classified into the corresponding I-O model sectors. For each import commodity, the second column identifies the major import using sectors. Then for each import using sector, Column 3 shows the total value of import disrupted in the 3-month period. Since economic sectors purchase production inputs from both local producers and importers, we compute the total input of a given commodity used as production input in a given sector in Column 4. The percentage of input disruption is then computed as the ratio of import disruption and total input used in each sector.

As discussed in Section IX, in the case of multiple input disruptions, to eliminate double-counting, we only count the input disruption that represents the largest production constraint in percentage terms for each sector. Therefore, in Table 6, for each major import-using sector, the % input disruption is determined as the most affected input in percentage terms as calculated in Table 5. The direct output losses of each sector during the 3-month port shutdown period (without any resilience adjustments) are calculated in the last column of Table 6. The total impacts of the import disruption are computed in Table 7. The direct output losses of the major import using sectors are $7.0 billion, which results in total supply-side impacts of $8.0 billion and total demand-side impacts of $8.9 billion. The total impacts are the sum of supply-side and demand-side impacts, net of the double-counted direct output losses. In addition, we cap the total losses of a sector as its total production output in the 3-month period. The total output impacts of all port import

disruptions are $9.6 billion, which represents a reduction of 53.9 percent of economic activity in the Port Arthur MSA. This implies an overall multiplier effect of 1.38 ($9.6 B / $7.0 B).

Not all the imports are used as intermediate inputs in the production processes. A portion of imports are final (finished) goods that are purchased by domestic end-users (consumers and government). The 3-month import disruption would also result in final goods losses of about $217 million. However, these losses do not generate any supply-side impacts because they are at the end of the production chain.

2. Resilience Case

a. Re-routing ships carrying imports. We assume 90% re-routing of the import shipping. However, we also assume that none of the re-routed crude oil and other petroleum refining products can be transported back to the Port Region through pipelines. Re-routing has the effect of reducing direct output losses to $4.5 billion. The total output losses can be reduced to $5.5 billion, or 30.8% of the total gross output.

b. Release of Strategic Petroleum Reserve (SPR). We assume that the release of the SPR can reduce the crude oil disruption by 4.16 million barrels (equivalent to around 20% of the total SPR drawdown in the aftermath of Hurricane Katrina). Use of SPR can reduce the direct output losses of the Port Region from $7.0 billion to $6.5 billion. The total output losses are reduced to $9.2 billion, or a reduction of 51.5% of the total gross output.

c. We considered the diversion of export commodities to importers of the same commodities to reduce the potential losses on both the import and export sides. Although we use a 51-sector I-O table, we use the trade data at 6-digit HS codes to match the export commodities with import commodities, so that we are diverting the same commodity whose importation is being stifled. The export diversion helps reduce the import disruption induced direct output loss from $7.0 billion to $6.0 billion. Gross output impacts are reduced to $8.4 billion, or 46.9 percent of total gross output in the region.

d. We assume the possibility of conservation of all inputs is 2 percent. This has the effect of reducing direct output losses to $6.8 billion, and total net losses to $9.5 billion, or an overall reduction of 53.1 percent in total gross output in the region.

e. Production recapture can help the economic sectors to make up their production losses during the port shutdown period at a later date. As shown in Appendix Table C, the recapture factors range from 15 to 49 percent. This resilience tactic can reduce the total gross output loss in the region from $9.6 billion to $5.1 billion, or from 53.9% to 28.5% of the regional gross output. Compared with the previous three resilience measures, production recapture has the greatest potential to reduce the total gross output loss.

f. After simulating the effects of the resilience measures separately, we combined all the above five resilience adjustments together. Again, these resilience adjustments are not additive. Conservation is applicable after re-routing & SPR release, inventories and export diversion are applied. Production rescheduling is applied directly to overall losses after all the other resilience adjustments have taken place. Applying all of the five resilience adjustments can reduce the output losses to $2.1 billion, or a reduction of only 11.7 percent of regional economic activity in the Port MSA Region. Therefore, in this 3-month Complete Port Shutdown scenario, resilience has the potential to reduce the economic disruption to the Port Region resulting from import disruption by 78 percent.

Table 8 presents the summary results of import disruption impacts of the 3-Month Complete Port Shutdown Scenario to the Port Region.

9.2 Impact Analysis of Export Disruption

An export disruption would not only result in direct impacts to the export producing sectors, but also generate demand-side effects to successive rounds of input supplying sectors of the export producing sectors. Reductions in final demand associated with reduction in major exports are computed in the last two columns of Table 9. Columns 2 and 3 of Table 9 present the domestic and foreign export data of the two Ports. Columns 4 and 5 show the domestic and foreign export data for the Port Region that are extracted from the IMPLAN I-O table. All of these export data are for 3-month period. The final demand impacts to the Port Region of the 3-month port disruption (which are presented in the last two columns of Table 9) are computed by comparing the numbers in Columns 2 and 4 for domestic export, and Columns 3 and 5 for foreign export. In both cases, the final demand reduction equals the smaller value in the comparison. This is because, for each sector/commodity, if the exports shipped out from the ports exceed those that are exported from the Port Region shown in the I-O table, there must be goods that are produced in other regions and then are transported to the ports for further waterborne shipment. On the other hand, if the amount of goods that is shipped out from the ports is lower than the total export indicated in the Port Region I-O table, there must be goods that are produced in the Port Region and are delivered through other transportation means to other regions or countries.

The first three numerical columns of Table 10 present the demand-side impacts of export disruptions by sector. The total output impacts are $4.0 billion, which represents a reduction of 22.5 percent of economic activity in the Port Arthur MSA. The overall multiplier effect is 1.23 ($4.0 B / $3.3 B).

The resilience tactic of export diversion can reduce the losses on both the import and export sides. The effects on the import loss reduction have been presented in the previous Section. The last three columns of Table 10 present the demand-side impacts of export disruption when we take the export diversion adjustment into account. The total gross output impacts decrease from $4 billion to $1.9 billion, or from 22.5% to 10.6% of the baseline total gross output in the Port Region.

9.3 Impact Analysis of Port On-site Operation and Activities Disruption

In order to estimate the economic impacts of the disruption of Port on-site operations and activities, we first determine the direct output (or revenue) of port operations. The demand-side I-O model will then be applied to compute the total impacts of port operation disruption.

Siegesmund et al. (2008) cited the work by Martin Associates (2006a), which estimated that the direct revenues of Port of Port Arthur and Port of Beaumont are $112.6M and $107.8M, respectively. Because we were not able to obtain the original Martin Associates report for Port of Port Arthur and Port of Beaumont, we were forced to draw some inferences. According to similar studies undertaken by Martin Associates for Port of Houston and Sabine Neches Waterway (the terminals along this waterway include those owned by Port of Port Arthur and Port of Beaumont), we find that the direct revenues reported in Martin Associates studies include not only the port operation itself, but also the revenues of firms and businesses that provide direct services to ports (see Appendix Tables H1 and H2). Our understanding is that the revenues of Maritime Services are the direct operation revenues of the ports. According to Appendix Table H1, the

revenues of Maritime Services account for 39% of the total direct revenues of Port of Houston, and Appendix Table H2 shows the percentage of Sabine Neches Waterway is about 63%. We thus use the average of these two figures, or 51%, for Port of Port Arthur and Port of Beaumont. With this percentage, the annual revenues of port operations of these two ports would be $112.4M (= ($112.6 + $107.8) × 51%).

According to the NAICS code, Port Operations belongs to sector 48831, which is part of the 3-direct NAICS sector of 488 Support Activities for Transportation. In the sectoring scheme of the Port Region 51-sector I-O table, NAICS sector 488 is aggregated in Sector 41, Other Transportation. Therefore, we simulate $28.1M ($112.4M divided by 4 to adjust for the port disruption duration) as the direct output reduction of Sector 41, and then use the demand-driven I-O model to compute the total economic impacts of port operation disruptions.

Table 11 presents the total impacts of port on-site operation disruption by sector. The total output impacts are $46 million. The ratio of the total impact to direct impact, which is 1.64, reflects the demand-side multiplier of the Port operation.

9.4 Total Impacts of the 3-Month Port Shutdown

The total impacts of the base case (without any resilience adjustment) for the 3-month port shutdown are presented in the first three numerical columns of Table 12. For each sector, the impacts from import disruption, export disruption, and port on-site option disruption are added together. We also cap the sectoral impacts to its total output level in the 3-month period, i.e., any overage is treated as double-counting in the multi-source disruption computation. The total output impacts are about $12.7 billion, or a 71% reduction of economic activity in the Port Arthur MSA.

The last two columns of Table 12 present the total impacts of the 3-month port shutdown to the Port Region after the incorporation of all resilience adjustments considered in this study. Applying all of these adjustments can reduce the output losses to $4.0 billion, or a reduction of only 22.5 percent of regional economic activity in the Port MSA Region. In other words, resilience measures have the potential to mute the regional economic losses by 68 percent in the 3-month Complete Port Shutdown scenario.

10 IMPACT ON THE U.S. OF A COMPLETE PORT SHUTDOWN

This section presents the economic impacts of Scenario 1 to the U.S. as a whole. Similar approaches as those used in the Port Region impact analysis for import disruption, export disruption, and port on-site operation disruption are used. Again, the trade data used in the analysis are presented in Appendix Tables E1 to E8. The U.S. I-O Table is presented in Appendix Table F2.

10.1 Impact Analysis of Import Disruption

1. Basic Case (without any resilience)

In order to calculate the direct output losses to the U.S. economy, we again first ascertain the major using sectors of each import commodity. In the Port Region import disruption analysis, the major import using sectors of both foreign import and domestic import can be determined by comparing the distribution of a given import commodity to each sector shown in the IMPLAN Industry Import Matrix for the Port Region.

However, the U.S. I-O Table, in which the entire country is treated as one region, contains only foreign import data. The domestic trade data are embedded in the inter-sectoral transaction flows in the I-O table. Therefore, for the foreign import data, we again use the IMPLAN Industry Import Matrix (the U.S. Import Table) to determine the major foreign import using sectors. For the domestic import data, we use the U.S. I-O Table to identify the major using sectors of those disrupted goods. Again, the criterion for determining the major users of a certain import or domestically produced good is that one sector uses more than 10% of the total amount of this import or good that is consumed in the national production activities.

To eliminate double-counting, we only count the input disruption that represents the largest production constraint in percentage terms for each sector. Also, for a given sector, we compare the highest input disruption percentages that are computed based on foreign import disruption and domestic import disruption. To further avoid double-counting, if the disrupted foreign import commodity and domestic import commodity are different commodities, we only use the input disruption with the higher disruption percentage. However, if a sector suffers the highest input disruption for the same commodity on both the foreign import side and domestic import side, we add the input disruption percentages on the two sides together.

The total impacts of the import disruption are computed in Table 13. The direct output losses of the major import using sectors are $31.4 billion, which results in total supply-side impacts of $92.4 billion and total demand-side impacts of $85.7 billion. The total net double-counting output impacts on the U.S. economy are $146.8 billion, which represents a reduction of 2.1 percent of total national gross output in the port shutdown period. This implies an overall multiplier effect of 4.67 ($146.8 B / $92.4 B). The impact on final (finished) goods resulting from import disruption is $1.86 billion.

2. Resilience Case

a. Re-routing. For the 3-month Complete Port Shutdown scenario, we assume that 90% of the import ships can be re-routed to alternative ports. Although we assume that the re-routed crude oil and petroleum refining products cannot be transported back to the Port Region, the effect of the 90% re-routing can be fully contained in the impact analysis to the U.S. as a whole. This is because, for example, the output losses of the refineries in the Port Region will be offset by the increased production activities in refineries in other regions from the national point of view. The 90% re-routing can substantially reduce the direct output losses to the U.S. from $31.4 billion to $3.1 billion. The total output losses are reduced to $14.7 billion, which represent a reduction of only 0.21% of the total gross output.

b. Release of Strategic Petroleum Reserve (SPR). We also analyze the effect of SPR release of 4.16 million barrels to the refineries in the Port Region. The SPR release can slightly reduce the direct output losses to the U.S. from $31.4 billion to $31.2 billion. The total output losses are reduced to $145.6 billion, or a reduction of 2.1 percent of the total gross output.

c. Export diversion. The export diversion helps reduce the direct output to $10.4 billion. Gross output impacts are reduced to $52.0 billion, or 0.8 percent of total gross output in the disruption period.

d. Conservation: A 2 percent conversation on all disrupted inputs had the effect of reducing direct output losses to $30.8 billion, and total net losses to $143.8 billion, or an overall reduction of 2.1 percent in total gross output.

e. Production recapture. This resilience tactic can reduce the total gross output loss for the U.S. from $146.8 billion to $84.4 billion, or from 2.1% to 1.2% of the total gross output.

f. Combination of the five resilience tactics. Applying all of the five resilience adjustments (in the same sequencing order as in the Port Region analysis) can reduce the output losses of import disruption to only $35.1 million, or a reduction of only 0.0005 percent of total economic activity in the U.S. Therefore, for Scenario 1, a 3-month complete shutdown of Ports of Port Arthur and Beaumont, resilience measures to import disruption have the potential to reduce the economic disruption to the U.S. by over 99 percent. Among the five resilience measures, re-routing ships to alternative ports has the greatest potential to reduce the losses.

Table 14 presents the summary results of import disruption impacts of the 3-month Complete Port Shutdown scenario to the U.S. economy.

10.2 Impact Analysis of Export Disruption

Table 15 present the impact results of export disruption. The first three numerical columns present the demand-side impacts of export disruptions by sector. The final demand impacts resulting from export disruption are $4.4 billion. The total output impacts are $18.1 billion, which represents a reduction of 0.3 percent of total U.S. gross output in the 3-month period. The overall multiplier effect is 4.1 ($18.1 B / $4.4 B).

The last three columns of Table 15 present the output loss reduction potential of export diversion. The total gross output impacts are reduced from $18.1 billion to $8.4 billion if the commodities of export can be diverted to the importer of the same commodities.

10.3 Impact Analysis of Port On-site Operation and Activities Disruption

Table 16 presents the demand-side impacts of port on-site operation disruption. The direct output loss of port services is the same as in the analysis for the Port Region, which is $28.1 million. However, in the impact analysis for the U.S. as a whole, we use the U.S. demand-side I-O model to compute the multiplier impacts of the port operation disruption. The total output impacts are $73.2 million. The ratio of the total impact to direct impact, which is 2.6, reflects the demand-side multiplier effects of Port operation disruption to the U.S.

10.4 Total Impacts of the 3-Month Port Shutdown to the U.S. Economy

Table 17 summarizes the total impacts of the 3-month port shutdown (including import, export, and port on-site operation disruptions) to the U.S. economy. The first two columns of Table 17 present the base case (no resilience) results. The total output impacts are about $164.9 billion, or a 2.4% reduction of the U.S. economic activity. The last two columns present the output impacts after taking all the resilience measures into consideration. The total output losses are reduced to $8.5 billion, or a 0.1% reduction of the total gross output. Most of the output losses are due to the export disruptions; however, the resilience measures of import disruption considered in this study can mute the total gross output losses on the import-side by over 99%.

Compared with the total output impacts of Scenario 1 for the Port Arthur/Beaumont Region, the national level impacts are higher in absolute terms. The total output impacts of the Base Case (without any resilience adjustments) for the Port Region are $12.7 billion, and the total output impacts for the U.S. are $164.9 billion. The difference in the total impacts between the Port region level and the national level stems from both the differences in the direct output losses and the multiplier effects. First, only a portion of the import commodities are used in the production activities in the Port Region. For example, the total value of foreign crude oil import at the two Ports was about $29 billion in 2008. However, based on the IMPLAN Industry Import Matrix of the Port Region, the total foreign imported crude oil that is refined in the Port Region was only about $13 billion. Essentially, the full impacts of the total foreign import crude oil disruption can only be captured in the national level analysis. Second, for many imported goods, the Port Region does not have the corresponding producing sectors in both the regional I-O table and the Industrial Import Table. That means those commodities are neither used as inputs nor produced in the Port Region. In such cases, the import and export disruption of those commodities will not affect the economic activity of the Port Region, but will affect the rest of the U.S. Finally, the multiplier effects on both the demand side and supply side at the national level are much larger than at the Port MSA regional level. In a small region like Port Arthur, the production inputs largely depend on the goods that are produced in other regions. At the same time, successive rounds of spending also leak out of a small region. At the same time, the losses in the Port region are a much larger proportion of their economy than are the national losses in relation to the entire U.S. economy.

The post-resilience total impacts for the U.S. are $8.5 billion, which are again higher than the post-resilience impacts for the Port Region, which are $4.6 billion. However, resilience has a higher potential to mute the total losses at the national level, (95 percent) than at the Port regional level (64 percent). The major reason is that re-routing of the import ships and export diversion only plays a very limited role in loss reduction in the Port Region, while they have the highest potential to reduce losses among all the resilience tactics at the national level. This is because we assume that the re-routed crude oil and petroleum refining products will not be further be transported to the Port Arthur/Beaumont Region, and most of the diversions happen to the commodities that are not used or produced in the Region. Therefore, re-routing and export diversion only have very limited effects in the Port Region impact analysis compared with the analysis for the nation as a whole.

11 IMPACT ANALYSIS OF A MEDIUM CONSERQUENCE SCENARIO

For the second scenario, we analyze the economic impacts of a much shorter and smaller scale Port shutdown scenario on the Port Region economy and on the U.S. economy. This Medium Consequence Scenario only leads to 4-day partial closure of the Ports.

In this scenario, a tank barge (inspected) controlled by a towboat (uninspected) collides with an anchored foreign flagged tank ship (subject to International Conventions and CG Port State Control examination) on the Neches River, Jefferson County, Texas. The #2 starboard fuel oil tank on the tank ship discharges approximately 27K Gallons of #6 heavy fuel oil into the Neches River, which is a navigable waterway of the U.S. The COTP closes the Neches River from lighted beacon #42 to the Veterans Memorial Bridge. The Federal On-Scene Coordinator requests assistance from the GULF STRIKE TEAM, of which 4 personnel assisted with cost documentation, site safety, and shoreline cleanup assessment. This scenario results in the closure of the Neches River from the Port of Beaumont to the intersection of the Gulf Intracoastal Waterway (GICW) at the Sabine River for 4 days. The Port of Port Arthur and deep draft

vessel traffic along the Sabine River/GICW out to Sabine Pass is unaffected. Towing vessel traffic from Lake Charles to Galveston Bay is unrestricted.

There are in total 75 inland tows and 20 ships affected by the closure of the Neches River channel in this scenario. It is assumed that 30% of the vessels, 6 of the 20 ships and 22 of the 70 towing vessels, are restricted to their berths or are confined within the Port of Beaumont and along the Neches River channel for the entire 4 day closure. All the remaining towing vessels are able to continue transiting the GICW along the Sabine River including the Port of Port Arthur. The remaining 14 ships will determine whether to wait at the port or to re-route to other ports nearby. For a short-term port closure case (less than 7 days) like this scenario, the ability of the shippers to find alternative ports would be limited. We assume in the re-routing resilience analysis that only 20% of the 14 ships, or 3 ships, will be diverted to other ports.

The 14 deep draft vessels awaiting at the Sabine Pass Anchorage or that are re-routed to other ports are loaded with crude oil, at an average weight of 572K barrels per ship ($75/bbl). The 6 ships restricted to berths along the Neches Waterway are crude carriers either offloading or in ballast (empty). Among the 22 affected tows/barges, 15 are carrying bunker fuel (fuel oil used in ships) at 90% capacity (2070 tons). The unit value of bunker fuel averages around $599 per ton ($85 per bbl). The remaining 7 barges are empty. Therefore, the total value of the affected crude oil import in this scenario is 14 × 572,000 × 75 = $600,600,000. The total value of fuel oil on the towing vessels is 15 × 2070 × 599 = $18,598,950. The fuel oil in this scenario is ships' consumables, not import goods to be used in the Port Region production activities. Therefore, the I-O analysis is not applicable to the fuel oil. In the following sub-sections, we use the supply-driven and demand-driven models to analyze the impacts of the disrupted crude oil.

11.1 Impact Analysis for the Port Region

11.1.1 IMPACT ANALYSIS OF IMPORT DISRUPTION

1. Basic Case (without any resilience)

According to the Port I-O table, the total value of crude oil used as production input by the Petroleum Refineries sector in the Port Region within 4-day period is $298 million, which is less than the total disrupted crude oil in this scenario ($601 million). Therefore, we assume that in the Basic Case (with no resilience considered), 100% of the production activities of the Petroleum Refineries sector in the Port Region are affected. This leads to a direct output loss of $384.8 million. Table 18 presents the total impacts of the Basic Case. The total supply-side impacts are $422.3 million and total demand-side impacts are $413.0 million. The total net double-counting output impacts on the Port Region economy are $450.2 million, which represents a reduction of 57.6 percent of total gross output of the region in the 4-day period.

2. Resilience Case

a. Re-routing. It is assumed that 20%, or 3 ships will be diverted to other ports. However, since none of the diverted crude oil will be transported back to the Port Arthur/Beaumont Region, re-routing does not have the effect to reduce the output losses of the Port Region.

b. Use of inventories. The Petroleum Refineries sector would have enough crude oil inventories for a 4-day crude oil input disruption. However, the daily re-supply of additives will again be a constraint to the production in this scenario. In the case that the waterway transportation is interrupted and the additives have to be transported by either rail or trucks, the refineries would have to reduce their

production to around 60% of their normal operating capacity. Therefore, we simulate the direct output loss of the Petroleum Refineries sector as 40% even if there are plenty of crude oil inventories. The direct output losses are reduced from $384.8 million to $153.9 million. The overall impacts are reduced to $180.2 million, or a reduction of 23 percent of total gross output of the region in the disruption period.

c. Export diversion. All the affected cargos in this scenario are imported crude oil. It is assumed that no export is disrupted. Therefore, export diversion is not applicable in this scenario.

d. Conservation. A 2 percent conversation on the disrupted crude oil inputs had the effect of reducing direct output losses to $377.1 million, and total net losses to $441.3 million, or an overall reduction of 56.4 percent in total gross output within the 4-day period.

e. Production recapture. Recapture of production activities after the resumption of input supply can reduce the total gross output loss from $450.2 million to $233.7 million, or from 57.6% to 29.9% of the total gross output.

f. Combination of all the above resilience tactics. Applying all of these resilience adjustments in a sequencing manner can reduce the output losses to $91.7 million, or a reduction of only 11.7 percent of total economic activity in the Port Region for a 4-day period. The resilience measures can reduce the total output losses induced by the 4-day crude oil import disruption by 80%.

Table 19 presents the summary results of import disruption impacts of the Medium Consequence Scenario to the Port Region economy.

11.1.2 IMPACT PORT ON-SITE OPERATIONS DISRUPTION

For economic losses associated with the disrupted port on-site activities, we adjust the estimate in the 3-month Complete Port Shutdown scenario by the length of port closure in the Medium Consequence Scenario. The direct output loss of port services is $1.2 million. The total demand-side output impact is $1.64 million.

11.1.3 TOTAL IMPACTS OF THE MEDIUM CONSEQUENCE SCENARIO TO THE PORT REGION

Table 20 summarizes the total impacts of the Medium Consequence Scenario to the Port Region economy. The total output impacts without any resilience adjustment are $452.2 million, or 57.8% of the 4-day total gross output of the Port Region. After taking all the resilience measures into account, the total output losses reduce to $93.7 million, or 12.0% of the total gross output.

11.2 Impact Analysis for the U.S.

11.2.1 IMPACT ANALYSIS OF IMPORT DISRUPTION

1. Basic Case (without any resilience)

According to the U.S. I-O table, the total value of the disrupted crude oil in the Medium Consequence Scenario accounts for 11.3% of total crude oil input (either imported from abroad or produced domestically)

used in the 4-day production of the Petroleum Refineries sector in the U.S. This leads to a direct output loss of $753 million. The total impacts of the Basic Case (with no resilience) are presented in Table 21. The total supply-side impacts are $2,840 million and total demand-side impacts are $1,645 million. The total net double-counting output impacts on the Port Region economy are $3,732 million, which represents a reduction of 1.2 percent of total gross output of the U.S. in the 4-day period.

2. Resilience Case

a. Re-routing. It is assumed that 20%, or 3 ships will be diverted to other ports. Therefore, the direct output losses after re-routing are reduced by 20%. The total output impacts are reduced to $2,986 million, or a reduction of 1% of the total gross output of the U.S. in the Port closure period.

b. Use of inventories. We again assume that the refineries in the Port Region would have to reduce their production to around 60% of their normal operating capacity because of the constraint of additive re-supply. We assume that in the refineries in other regions, there are sufficient crude oil and additives in the inventories to maintain the production. Therefore, we simulate the direct output loss of the Petroleum Refineries sector as 40% × $384.8 million = $153.9 million. This resilience tactic can reduce the overall impacts to the U.S. economy to $763 million, or a reduction of 0.3 percent of total gross output in the 4-day period.

c. Export diversion. Again, export diversion is not applicable in this scenario.

d. Conservation. A 2 percent conversation on the disrupted crude oil inputs had the effect of reducing direct output losses to $738 million, and total net losses to $3,658 million, or an overall reduction of 1.2 percent in the U.S. total gross output within the port closure period.

e. Production recapture. Recapture of production activities after the resumption of input supply can reduce the total gross output loss to $2,117 million, or 0.7% of the total gross output.

f. Combination of all the above resilience tactics. Applying all of these resilience adjustments in a sequencing manner can reduce the output losses to $339 million, or a reduction of only 0.11 percent of total economic activity of the U.S. for a 4-day period. The resilience measures can reduce the total output losses induced by the 4-day import disruption by 91%.

Table 22 presents the summary results of import disruption impacts of the Medium Consequence Scenario to the U.S. economy.

11.2.2 IMPACT PORT ON-SITE OPERATIONS DISRUPTION

We again adjust the estimate in the 3-month Complete Port Shutdown scenario by the length of port closure in the Medium Consequence Scenario. Also, the U.S. I-O demand-side driven model is used to compute the total impacts of the disrupted Port on-site operations. The direct output loss of port services is $1.2 million. The total demand-side output impact is $2.6 million.

11.2.3 TOTAL IMPACTS OF THE MEDIUM CONSEQUENCE SCENARIO TO THE U.S. ECONOMY

Table 23 summarizes the total impacts of the Medium Consequence Scenario to the U.S. economy. The total output impacts without the application of any resilience adjustment are $3,736 million, or 1.2% of the 4-day total gross output of the nation. After taking all the resilience measures into consideration, the total output losses reduce to $342 million, or 0.11% of the total gross output.

Compared with the total output impacts for the Port Arthur/Beaumont Region, the national level impacts are higher in absolute terms without taking any resilience adjustments into consideration. The total output impacts for the Port Region are $$452.2 million, while the total impacts for the U.S. are $3,736 million. The difference in the total impacts between the Port region level and the national level stems from both the differences in the direct output losses and the multiplier effects. For the direct output losses, only about half of the disrupted crude oil import in this scenario is used in the refineries in the Port Region. As for the multiplier effects, both the demand-side and supply-side multipliers of the U.S. are larger than the regional multipliers of the Port MSA region. However, the losses in the Port Region represent a much larger proportion of their economy than are the national losses in relation to the entire U.S. economy.

The post-resilience total impacts for the U.S. are $342.4 million, which are again higher than the post-resilience impacts for the Port Region, which are $93.72 million. However, if we compare the pre- and port resilience impacts for the U.S. and for the Port Region, we can see that similar as in the Complete Port Shutdown Scenario, resilience has a higher potential to mute the total losses at the national level (91 percent), than at the Port regional level (79 percent). The major reason is that re-routing does not have any effect to reduce the output losses at the Port Region, since we assume that the re-routed crude oil will be refined in the refineries outside of the Port Region. In addition, due to the constraint in daily additive re-supply, the refineries in the Port Region have to reduce their production level to 60% of their normal capacity even if there are sufficient crude oil inventories for the 4-day period. We assume that the additive constraint does not apply to the refineries in the rest of the U.S.

12 OTHER IMPACTS

In addition to the major direct and indirect economic consequences modeled through the use of I-O analysis in this report, three additional cost impacts are estimated:

- *Economic cost of oil and chemical spills.* These affect water quality and ecosystems. Below, we measured the direct economic impacts. Indirect impacts caused by these spills are for the most part non-applicable because the impacts are "non-market values." The exceptions are market-oriented impacts relating to recreation, tourism, and commercial fishing.
- *Cost of delay caused by port shutdowns and diversions of shipping.* These are real resource costs but their indirect effects cannot be readily modeled in an I-O framework. The indirect effects stem from the increased costs of production/delivery of key products, which would ordinarily stunt demand directly and then lead to further multiplier effects. These impacts, however, are likely to be only a very small proportion of total economic consequences of the port disruptions we estimate. I-O analysis is not readily capable of analyzing the ramifications of cost increases.
- *Security value of oil released from the Strategic Petroleum Reserve (SPR).* Crude oil released from the SPR for use by refineries in the Port Arthur/Beaumont Area to compensate for tanker disruptions cannot simultaneously safeguard the U.S. from a strategic disruption like the 1973 Arab oil embargo or any other interruption. Below we estimate the direct security premium cost associated with these SPR releases. Again, only direct costs are counted, since this is a non-market value that does not translate into any price or quantity multiplier effect.

A. Economic Costs of Oil Spills

In this section, we estimate natural resource damages due to a hypothetical 27,000 gallon oil spill in the Neches River, Jefferson County, Texas, associated with our mid-level port disruption scenario. Ando and Khanna (2004) review the methods for estimating natural resource damages and argue that these should exhibit six properties. The methods should be simple to use, have legal recognition, be transparent, the damage estimates should vary with scope, the net present values should be calculated appropriately, and they should be unbiased estimates of public use and nonuse values. In the absence of the time and money resources necessary to conduct a primary data study of these damages, states have developed simplified methods for estimating natural resource damages (e.g., Faass 2010). Ando and Khanna determine that only five states have developed methods that are simple to use but no state meets each of the other five properties. In contrast, they argue that benefit transfer, while not easy to use, can potentially meet each of the other five properties.

In this study we use the benefit transfer approach to estimate natural resource damages (Wilson and Hoehn 2006). This method involves the application of existing benefit estimates to current policy problems for which no benefit estimates exist. The process typically involves a review of the economic literature, collection of applicable benefit estimates, and adjustment of those estimates for the current policy problem.

There are several types of benefit transfer. The first is known as benefit estimate transfer. In this method existing benefit estimates are used without adjustment. The accuracy of the benefit estimate transfer is a function of geographic proximity of the two estimates, the age of the study that produced the existing benefit estimate, the similarity of the policy, environmental quality change, and socioeconomic status of the relevant populations.

The benefit function transfer is similar to the benefit estimate transfer but it allows consideration for other variables that might cause divergence between benefit estimates such as the quality change and socioeconomic characteristics. In the best of situations each of these variables is measured and is available in an empirical valuation function. Again, the accuracy of the benefit transfer is a function of geographic proximity and the age of the study that produced the existing benefit function (see Dumas et al. 2005) for an example.

A third type of benefit transfer method is similar in practice to benefit function transfer. But, instead of relying on a single study to develop the benefit function, a meta-analysis function of all existing studies is used. A meta-analysis function is developed after an extensive literature review of all relevant studies. Benefit estimates and characteristics of these studies are then recorded in a data base. The data base is then statistically analyzed to develop a meta-analysis benefit function.

Once an individual or household benefit estimate is developed the final step in a benefit transfer is determination of the market area. In other words, the benefit estimate is aggregated over the most relevant geographic region and population. The region could be narrow or wide-ranging, the benefit estimates could be constant or, more likely, a declining function of distance from the policy site.

In the current policy situation, unfortunately, a review of the literature finds only a few published studies of oil spill damages and none of these are appropriate for the task at hand. Cohen (1986) evaluates the benefits and costs of the U.S. Coast Guard's oil spill prevention program and assumes an average environmental damage of $6 per gallon of oil spilled.[5] It is unclear how this estimate was developed. Carson et al. (2003)

estimate the national environmental damages from the Exxon Valdez oil spill using the contingent valuation method. Their aggregate estimate of damages is $4.67 billion. Since the Exxon Valdez oil spill was 10.8 million gallons, the environmental damage is $423 per gallon. Since per gallon damage estimates are insensitive to population and other study characteristics we conclude that none of these studies are appropriate for benefit transfer. Carson et al. (2004) estimate the value of oil spill prevention in California but fail to consider the scope of the spill, focusing their attention on avoiding damages to 12,000 birds. Loureiro et al. (2009) estimate damages from the 20 million gallon Prestige oil spill in Spain. Their estimate of the aggregate economics damages is about $42 per gallon.[6] Carson et al. (2003) also present a statistical valuation function that could be used for benefit function transfer. However, the Exxon Valdez context is significantly different from the current context in terms of the scope of the damages and this valuation function is determined to be inappropriate for the current context.

In contrast to traditional benefit transfer we use an approach similar to the one developed by Whitehead and Rose (2009) for estimating the economic benefits of natural hazard mitigation policies. In this approach, a variety of environmental impacts are assessed for earthquake, flood and wind hazards and rules for sensitivity analyses are developed. The impacts include water quality and wetlands. The approach might be termed the economic activity approach, because it focuses mainly on "use values" of natural resources associated with commercial and recreational activities.

In April 1993 88,000 gallons of oil spilled in the Neches River affecting about 31 acres of wildlife habitat. Scaling the habitat acreage down for the current hypothetical oil spill leads to an estimate of about 10 acres of habitat. We assume that each acre is a wetland that supports outdoor recreation activities. In order to avoid double-counting of damages we avoid valuation of wetlands directly and assume that they contribute to the production of outdoor recreation activities. We assume that recreational fishing and outdoor recreation (e.g., recreational boating) activities are disrupted for one year. Two household populations are considered using year 2000 Census population increased by the state of Texas population increase from 2000-2010. The first is the population of Jefferson County, Texas. The second includes Jefferson County and the surrounding counties of Hardin Orange, Chambers, Liberty and Cameron Parish, LA.

According to the 2000 National Survey of Recreation and the Environment (NSRE), 31 percent and 36 percent of Texas residents participate in warm water fishing and recreational boating. The average number days in each activity are 13 and 14 annually, respectively. These are mean values of recreation participation and days for all of Texas. Conditioning these estimates on socioeconomic characteristics and employing variables for Jefferson County and the surrounding counties could lead to more accurate estimates of participation. The number of days fishing and boating resisted modeling so we use the unconditional mean.

We estimate a linear probability model for fishing and boating participation with age, race, sex, household size, education and household income as independent variables. We find that fishing and hunting participation is higher for white males, increases with income and decreases with age. Fishing participation increases with household size. Education does not have a statistically significant effect on participation. The average age from the NSRE for Texas residents is 44. We find little evidence from the 2000 U.S. Census that the age or education distribution for all of Texas is any different for Jefferson County. The NSRE is representative of the Texas population estimates from the U.S. Census for household size and race: 2.74 and 82% white. The NSRE household income level is $55,000 while the U.S. Census estimate is $50,000. For these variables we use the Jefferson County estimates from the U.S. Census to predict participation. With 50% male, household size of 2.55, 61% white and $44,000 household income, we estimate that fishing and boating participation is lower than the unconditional estimates from the NSRE, 27% and 33%.

The mean estimates of recreational value developed from the literature by Rosenberger and Loomis (2001) and inflated to 2008 dollars, are $49.37 per day for fishing and $48.38 per day for boating. Since the Neches River channel is closed for four days we estimate that 1.1% of the annual days fishing and boating would be lost due to the oil spill. Johnston, Besedin and Wardwell (2003) conduct a meta-analysis of water quality valuation studies with a focus of differentiating between use value and nonuse value. They find that the each $1 increase in use value is associated with a 0.67% increase in nonuse values. Applying these values to Jefferson County yields a recreational fishing and boating damage of $469,812, about $17.8 per gallon spilled.

The estimates above represent nonmarket costs of the oil spill which are different from the market costs, or lost expenditures (Dumas, Schuhmann and Whitehead, 2005). The market costs of those not taking fishing and boating trips due to the oil spill can be estimated using the same logic as above and replacing the consumer surplus estimates with an estimate of expenditure per day. Expenditures per fishing day for Texas are obtained from the National Survey of Fishing, Hunting and Wildlife Associated-Recreation (USFWS, 2006) and inflated by the CPI to 2010 dollars. The cost per day is $39.5 and represents trip related expenditures, excluding equipment costs such as boats and fishing gear. We apply this fishing trip value to boating trips as well. The aggregate recreation expenditures lost as a result of the oil spill is $379,995 for Jefferson County and $729,393 for the region. The indirect and induced effects of this disruption are computed with the use of our Port Region I-O table yielding a total economic impact of $631,662 for Jefferson County and $1,212,462 for the region in the Medium Consequence Scenario.

We characterize this as our base case estimate because they are constructed with estimates from the literature and the NSRE database. However, we are not suggesting that the base case estimates are our best estimates or midpoint estimates. Indeed, our base case estimates are likely biased for several reasons. Further examination of the assumptions embodied in these estimates and refinements of values is warranted. In the next section we pursue a Monte Carlo sensitivity analysis in order to develop a plausible distribution of nonmarket costs of the oil spill.

It is likely that the site-specific Neches River fishing and boating recreation participation is lower than overall participation in fishing and boating activities. We have also attributed all of the average annual number of days in these activities to the Neches River site. Sensitivity analysis should examine lower estimates leading to lower damages. On the other hand, we have adopted the assumption that recreation activity resumes as soon as the boating channel is reopened and that recreation and nonuse values accrue only to residents of Jefferson County. Reexamination of these assumptions would lead to a longer period of damages and a larger population over which to aggregate. Both will lead to higher estimates of damage.

Since we do not have a statistical distribution over our uncertain values we adopt a uniform distribution over the plausible range of most parameters. For recreation participation and days spent in the activity we consider a range from zero to the point estimates used above. For participation and days lost, we find it reasonable to include zero impacts since participants could substitute alternative sites or time periods for the recreation days lost on the Neches River. For the time period lost we allow the site closure to range from four days to 30 days. For the population estimate we consider a range on the low end to include only the Jefferson County household population (2010 population estimate of 111,000) and upwards to include the household population of the surrounding counties of Hardin, Orange, Chambers and Liberty in Texas and Cameron Parish, LA (214,000). By using the uniform distribution for each uncertain parameter, we are implicitly assuming that the best estimate is the midpoint of the range of values and each value in the range is equally likely.

For the recreation values per day, we also consider a range from zero to the point estimate used above. The value of zero is likely beyond the reasonable lower bound but the site-specific value per day for river recreation is likely approaching zero (e.g., see Phaneuf 2002). Instead of the uniform distribution, we use the normal distribution with a mean of the midpoint of the range of plausible values, about $25, and a standard deviation of 6. Since nonuse values are a very low portion of total values, we abstain from sensitivity analysis over this value.

In the Monte Carlo sensitivity analysis we allow variation of each random parameter simultaneously. We perform 1000 simulations and find average damages from the Neches River oil spill equal to $350,000 with a median of $297,000. The 90% confidence interval is found by trimming the lowest and highest 50 values. The 90% confidence interval is $44,000 to $1,000,000. Per gallon spilled, the average damage is $14 with a median of $11. The 90% confidence interval is $2 to $38.

B. Cost of Delay Caused by Ports Shutdown and Diversion of Shipping

The delay costs are estimated for the affected ships in the Medium Consequence Scenario. Previous experiences with similar durations of port shutdown (less than 7 days) show that shippers tend to wait at the Port if they receive reliable and reasonable predictions from the Port Coordination Team regarding the timelines of port reopening. Given the short period of port shutdown in the Medium Consequence Scenario, it is difficult for the shippers to find alternative routes. Therefore, in this scenario, we assume that only 20% of the ships will be diverted to other ports. There are in total 75 inland tows and 20 ships affected by the closure of the Neches River channel in the Medium Consequence Scenario. It is assumed that 6 of the 20 ships (30%) and 22 of the 70 towing vessels (30%) are restricted to their berths or are confined within the Port of Beaumont and along the Neches River channel for the entire 4 day closure. The remaining 53 towing vessels are able to continue transiting the GICW along the Sabine River including the Port of Port Arthur. Towing vessel traffic along the GICW that was en route to the Port of Beaumont and Neches River channel has been diverted to alternate destinations. For the remaining 14 cargo ships that are not confined within the shutdown area, 20%, or 3 ships, will choose to divert to other ports. However, the re-routing will on average cost around 1.5 days delay time (assuming the ships are heading to nearby ports along the Gulf Coast). The other 11 ships will be standing by at the ports waiting for the resumption of port operations. Based on Port Arthur Vessel Traffic Service data, the per day and per vessel delay costs of tows and ships are $8,000 and $45,000, respectively. The total delay costs are calculated as:

- *22 Inland Tows Stopped × $8,000/day × 4 days = $704,000*
- *17 Ships Confined at the Ports or Choose not to Divert7 × $45,000/day × 4 days = $3,060,000*
- *3 Diverted Ships × $45,000/day × 1.5 days = $202,500*

Total Ship and Tow Delay Costs = $704,000 + $3,060,000 + $202,500 = $3,966,500

For the 3-month Complete Port Shutdown scenario, we assume that 90% of the ships will be re-routed. The delay costs may apply in the beginning of the port shutdown period, as ships that head to or have arrived at the Ports have to find and re-rout to an alternative port. However, as the shippers begin to know the shutdown of the Ports, they will arrange the ships to go through alternative routes directly. In such cases, there will be minimal delay costs. Given the complexity to estimate this gradually phased-out delay costs, and after all, these costs would be relatively small compared with the total economic impacts of the port shutdown in 3-month period, we did not estimate the delay costs for the 3-month Complete Port Shutdown

scenario. However, we surmise that they would be a very small proportion of total impacts, because of the magnitude of the supply-side and demand-side disruption impacts.

C. Security Value of Oil released from the Strategic Petroleum Reserve

It is the policy of the U.S. government to release crude oil from the nation's Strategic Petroleum Reserve (SPR) in case of emergencies, not limited to military and political events. For example, 20.8 million barrels were released to refineries in the aftermath of Hurricane Katrina,[8] and, closer to the Port Arthur/Beaumont Area, 5.4 million barrels were released after Hurricanes Gustav and Ike (Citation, 2010). If this oil is replaced after shortly thereafter, there is no real resource cost to the Government of the basic oil inventory, except for the time value of money (imputed interest charge, paid or unpaid) associated the loan.

However, the oil in the SPR has an additional value—the potential ability to cushion the U.S. military and economy from a shortfall in oil supplies in case of an emergency such as the Arab Oil Embargo, an act of terrorism, a natural disaster, or a major technological accident. This value is known as the "security premium," and it is calculated as the intersection of the probability weighted marginal benefits of the use of this oil and its marginal cost. The marginal benefits are the economic output to which the oil contributes in an emergency, with the probabilities relating to the likelihood of an emergency. The marginal costs are the costs of storage and the time value of money, or opportunity cost of tying up funds in oil inventories (essentially an imputed interest charge). The value of the oil itself is not part of the security premium.

Current estimates of the security premium are about $5 per barrel associated with a price of crude oil of $100 per barrel (Brown and Huntington, 2010). In our study, we assume a price per barrel of crude oil of $75, so we adjust this security premium estimate downward by 25% to $3.75.

It would be speculative to assume that this large a drawdown would be approved or realized based on one small port region being unable to receive crude stocks and no other production and refining facilities are affected across the region or the GOM. Many other factors at the national/international level would be in play. For the purpose of this report, we assume a 20% adjustment to the Katrina 3-month SPR drawdown of 20.8 million barrels is reasonable, this yields an estimate of 4.16 million barrels for our Complete Port Disruption Scenario. Based on Year 2008 trade data for the ports of Port Arthur and Beaumont, the total crude oil import disruption during the 3-month period is 99.24 million barrels, of which 44.15 million barrels are refined in the Port Region. One of resilience tactics we analyze is the re-routing of ships to other ports of the U.S. For the 3-month period, we assume that 90% of the ships that originally head to Port Arthur/Beaumont would be able to find alternative ports. However, we also assume that none of the re-routed crude oil will be transported back through pipelines to the Port Region; instead, the diverted crude oil will be processed in refineries outside of the Port Region. Therefore, we assume that all of the crude oil released from SPR will be used in the key refinery facilities in the Port Arthur/Beaumont Region to maintain a minimal level of operations. The 4.16 million barrels of SPR would account for around 10% of the shortfall of the crude oil in the Port Region.

Thus our estimate of the total security premium cost of release of crude oil from the SPR in association with our Full Disruption Scenario is: $3.75 times 4.16 million or $15.6 million in 2008 dollars.

D. Other Costs

We should also note some losses that were not measured. First are adverse behavioral responses that would likely ensue from terrorist attack or technological accident that would release biological/chemical/radiological agent disrupting the port. Such incidents could instill fear of lingering contamination of the port and its future cargo. Previous studies (e.g., Geisecke et al., 2011) indicate that a "fear factor" can increase total BI losses by more than a factor of 10 over and above the ordinary resource loss effects measured here.

Second, is the prospect of another long-term effect--the permanent loss of business from a port shutdown. Chang (2000) and others have documented the fact that ports experiencing disruptions do not readily return to baseline operating levels for a number of years if ever. It appears that shippers find favor with the new ports themselves and also gain appreciation of diversifying their destinations as a risk management strategy.

13 SUMMARY

This report has presented simulations of two major disruptions to Port Arthur and Port Beaumont. One involved limited access to shipping for four days, and the other is a complete port shutdown for ninety days. The scenarios were chosen to represent a typical accident and an upper-bound event. The estimates of economic losses are key to developing risk management strategies for marine safety programs. In a benefit-cost analysis framework, the avoidance of these losses represents the first step in measuring benefits of safety programs. These benefits next need to be multiplied by their probability of occurrence, and then this risk-adjusted benefit measure needs to be juxtaposed to the direct and indirect costs of implementing a safety program.

Our analysis extends far beyond the immediate damage to ships or port facilities. It focuses on nearly all direct and indirect business interruptions in the ports' surrounding economic area and the nation as a whole. Essentially the curtailment of imports and exports, as well as of the port operations themselves, translates into a chain of ripple, or multiplier, effects. For example, petroleum refineries in the port area and elsewhere are unable to keep operating, and their customers will suffer from a decline in the availability of key inputs. A decrease in production off-site will lead to further curtailments of more customers down the supply chain. Also, for example, reductions in port operation mean a decrease in the ports' purchases of electricity, business services, labor, etc. These in turn cause further decreases in demand up the supply-chain, as business service industries purchase fewer inputs and workers as a whole have less income to spend.

At the same time, the economy is resilient at several levels. Producing sectors in each round of the supply chain can use inventories and conserve inputs, ships can be re-routed to other ports, and many businesses can recapture lost production by working overtime or extra shifts following the resumption of normal port operations. Resilience can greatly reduce the BI losses.

Our results indicate that a 90-day Port Arthur/Port Beaumont shutdown would result in BI losses of $13 billion, or 71 percent of the Port Arthur/Port Beaumont MSA for that period. However, resilience can reduce these losses by two-thirds. The potential impact on the U.S. economy of the 90-day shutdown is $165 billion, or 2.4 percent of the national economy. Here resilience is even more powerful, because a broader range of options are available so as to reduce these losses by nearly 95 percent to less than $10

billion. The most effective resilience tactics at the national level are rerouting of ships, diverting exports to substitute for imports, and use of inventories.

The Medium Consequence Scenario yields much lower BI losses in absolute terms because of the shorter duration of port disruption. The losses to the Port Region are $452 million and $93.7 million before and after resilience, respectively. On the national level, the impacts are $3.7 billion without taking account of any resilience measures. Resilience can reduce the losses by 91%, to the level of $342 million. The most effective resilience tactics for this scenario at the national level are use of inventories and production recapture.

We also measure some miscellaneous costs of the disruption. These include environmental damage estimates of the oil spill associated with a ship accident of $1.2 million, the direct costs of shipping delays of $4 million, and the loss of security value of oil borrowed from the Strategic Petroleum Reserve of $15.6 million. The first two of these pertains to the 4-day scenario, and the third to the 90-day scenario. However, they wind up being a relatively trivial part of total losses.

Our methodology has been carefully developed for the study at hand. However, it is readily generalizable

to disruptions of other types and at other ports. We have thus developed and successfully applied an important risk management tool for the U.S. Coast Guard and other port stakeholders.

Summary Table 1. Gross output impacts of port shutdown scenarios.

Scenario	Output Impact w/o Resilience		Output Impact w/ Resilience	
	Level (million 2008$)	Percent*	Level (million 2008$)	Percent*
Medium Consequence Scenario				
Port Region	452.2	57.8%	93.7	12.0%
U.S.	3,735.6	1.2%	342.4	0.1%
Complete Port Shutdown Scenario				
Port Region	12,729.4	71.4%	4,021.7	22.5%
U.S.	164,903.5	2.4%	8,506.1	0.1%

* The percentage impacts are with respect to the total regional or national output in the Port Shutdown period, i.e., 4 days for the Medium Consequence Scenario and 3 months for the Complete Port Shutdown Scenario.

Summary Table 2. Miscellaneous costs.

Category	Cost (million 2008$)
Economic Costs of Oil Spill	0.7
Delay Costs of Shipping	4.0
Security Value of Oil Release from SPR	15.6
Total	20.3

Table 1. Summary of port closures studies.

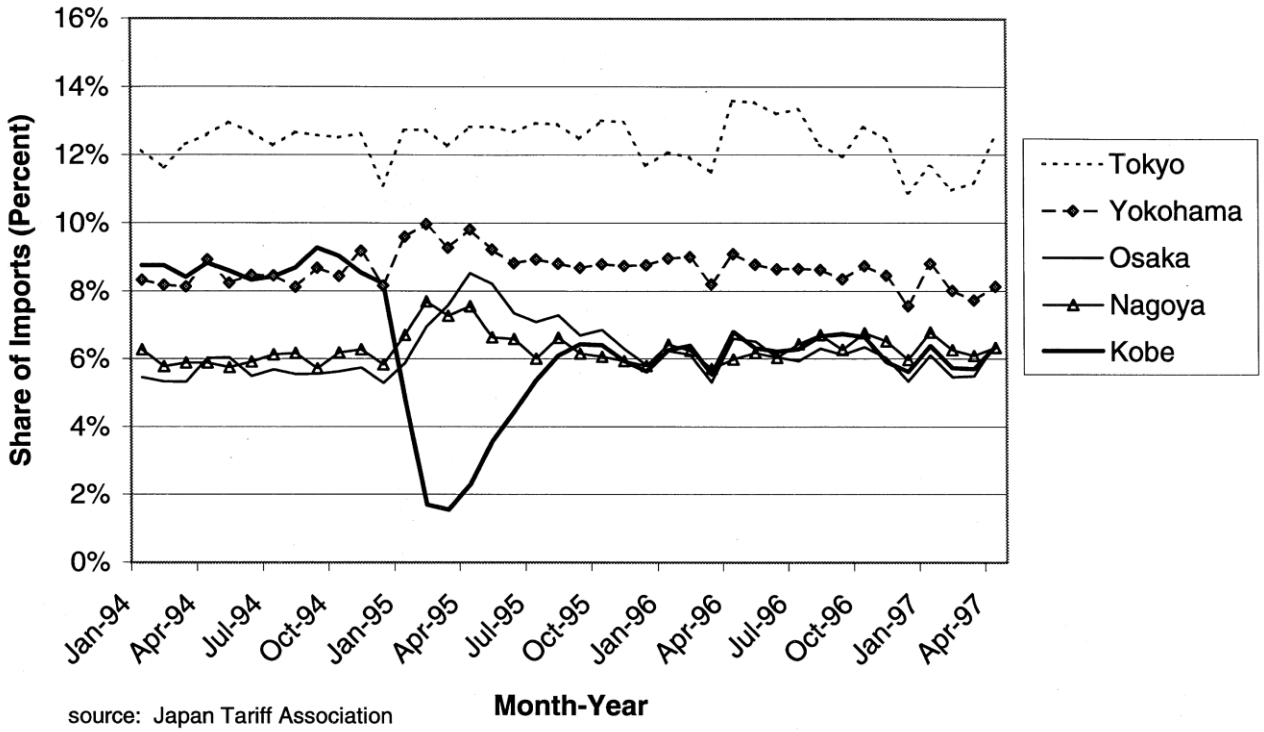
Author (date)	Topic/Duration	Geographic Area Direct/Indirect	Methodology	Resilience	Results
Park et al. (2007)	Terrorist attacks on three major US ports One-month closure	Direct final demand losses for export and import of LA/LB, Houston, NY/NJ ports / total impacts on all U.S. states plus Rest of World	WISERTrade data and the WCUS (Waterborne Commerce of the U.S.) data for estimation of direct losses. Direct loss = annual imports/exports ÷12 Demand-driven NIEMO is applied to export loss; only direct impacts of import loss are included in total effects	None	US Total: -$49B Rest of World: -1.4B
Park (2008)	Dirty bomb attacks on LA & LB Ports One-month closure	Direct impacts CA/ indirect impacts on all U.S. states plus Rest of World	WISERTrade data and the WCUS data for estimation of direct losses Demand- & supply-driven NIEMO (conventional model except for multi-regional linkages) are applied to direct loss of exports/imports	None "without any mitigations and substitutions"	Export: US Total: -$8.5B Rest of World: -$0.5B Import: US Total: -$26B Rest of World: -$0.9B
Park et al. (2008)	2002 shutdown of the LA-LB ports The shutdown lasts 11 days; analysis covers 5 months (shutdown month + 4 months after)	Direct impacts of LA, SD, SF, Columbia-Snake River, and Seattle Customs Districts / total impacts on all U.S. states	Multilevel linear regression model to estimate direct final demand losses, including dummy variables to reflect possible periodic, port, and modal substitutions. Final demand losses are computed as $D = \hat{Y} - Y$ Y: actual foreign import/export $\hat{Y}$: estimated import/export via the regression model Demand- & supply-driven NIEMO are applied to direct loss of exports/imports	Direct impact mitigation via substitutions over time, by mode and by port	Export: US Total: -$3B Import: US Total: +$579M (WA & OR experienced positive direct impacts due to port shift)

Table 1. Summary of port closures studies (Continued).

Author (date)	Topic/Duration	Geographic Area Direct/Indirect	Methodology	Resilience	Results
CBO (2006)	Economic costs of disrupting container shipments through ports of LA/LB S1: one-week shutdown to all container traffic through LA/LB ports S2: three-year shutdown to all container traffic through LA/LB ports and one-week to all U.S. ports	Direct impacts of LA/LB / total impacts of US economy	Inforum Lift (Long-term Interindustry Forecasting Tool) model Imports: Direct import loss = imports expected to arrive in LA/LB – imports assumed to be diverted to other ports or modes of transportation To simulate import reductions, Inforum raised import prices, which results in production increase of domestic competitors of foreign imports and consumption substitution of the U.S. consumers. Exports: Containerized exports through LA/LB ports are small, so this study assumes all exports can be diverted to other ports	Shift to other ports and transportation modes. Assumption: 1st yr 35% 2nd yr 55% 3rd yr 70% (assume there would be construction of additional ports and air-freight capacity) Substitutions between domestic produced goods and imports are embedded in the Lift model simulation	One-week shutdown: $65M-$150M per day Three-year shutdown: $125M-$200M per day
Chang (2000)	Loss, recovery and competition at the Port of Kobe after the 1995 earthquake Over two years for complete physical reconstruction	Direct loss at Port of Kobe Does not compute total loss to the region or the nation	Statistical data on international trade in regression analysis	Share of imports diverted to other major Japanese ports are reported	Likely long-term loss to other world ports: 34% Share of imports change among major Japanese ports: see Figure A

Table 1. Summary of port closures studies (Continued).

Author (date)	Topic/Duration	Geographic Area Direct/Indirect	Methodology	Resilience	Results
Rose et al. (2009)	Complete shutdown of the U.S. borders to people and goods for one year	Total impacts to the U.S. economy	REMI Policy Insight Model Import: Reduce "Share of Imports from Rest of World" for each REMI sector by 100% plus increase "Production Cost" of domestic substitute producing sectors Export: Reduce "Industry Sales / International Exports" by total amount of baseline exports	Utilize excess capacity to produce import substitutes (assume production cost increase above the use of 20% excess capacity) Divert exports to substitute for import shortage	Import: -$278 B GDP losses (2000$) Export: -$1,360 B GDP losses (2000$)



Source: Chang (2000)

Figure 4. Share of Japan's import trade by port, January 1994-April 1997.

Table 2. Resilience measures.

Resilience Type	Possible Data Source	Notes
Resilience at Port Level		
Shift to Other Ports	CBO (2006) study assumes that within the first year of shutdown of LA/LB ports, 35% of baseline import container shipments would arrive elsewhere in the U.S. The assumptions for the second and third years are 55% and 70%, respectively. Containerized exports through LA/LB ports are small, so CBO study assumes all exports can be diverted to other ports. The regression analysis in Park et al. (2008) indicates that the total losses to the western ports as a whole are only 25% of the losses to the Port of LA. Many ports experience positive impacts, which can be explained as taking over the trade from LA. Therefore, the implicit port substitution effects in the Park study are likely to reduce around 75% of the direct impact of import shutdown. However, no similar effect is found on the export side. Cohen (2002) pointed out that during a West Coast dock strike, only a small portion of shipments could be rerouted to East Coast and Gulf ports. His estimate for a recessionary circumstance (for which the capacity restraints on re-routing is relatively light) would be 10-15% at maximum. The major reason is that as ports become specialized in handling specific types of shipments and cargos, carriers have less flexibility to reroute their cargos, e.g., the West Coast ports can handle extra wide transpacific container ships, which are too large to transit the Panama Canal, or be accommodated at most East Coast ports. Knatz (2006) indicates that during the 10-day lockout of LB/LA Ports in October 2002, only about 10% of the cargo was diverted through the Panama Canal to the East Coast ports in Georgia and South Carolina. However, those diversions are enough to challenge the capacity limit of those East Coast ports.	CBO (2006) assumes that the increased costs of diverting export goods to alternative West Coast ports are small, since many of those goods have already been transported to the West Coast from other places of the country. Delay cost: Hummels (2001) estimated that for import goods, each day of delay (caused by re-routing to other ports) would cost the importer 0.8% of the value of the goods.

Table 2. Resilience measures (Continued)

Resilience Type	Possible Data Source	Notes
Resilience at Port Level (Continued)		
Transportation Modal Substitution	Park et al. (2008) regression analysis found only slight substitution on the import side and no evidence of modal substitutions on the export side.	
Recapture After Port Re-Opens	Refer to Water Transportation sector in Appendix C.	
Resilience at Producing Sectoral Level		
Inventories	Data on Real Inventories for manufacturing sectors are shown in Appendix Table C1. Need to distinguish inventories in the hands of producers from inventories in the hands of customers; the latter are key.	
Conservation	Table C2 shows the resilience factors we put together for the Border Closure study (Rose et al., 2009). The conservation factor is assumed to be 2% for all sectors. However, we did not actually apply this resilience adjustment in the study. We only mentioned in the paper that "it is unlikely that conservation would be able to reduce the impacts by more than a few percent points".	Authors' assumption
Excess Capacity of Domestic Production (for import loss adjustment)	See Appendix Table C2.	Rose et al. (2009) assumed that excess capacity of 20% on average can be accessed to make up the import shortfalls and also assumed that the utilization of excess capacity at this level will not result in noticeable production cost increases.
Production Recapture	Appendix Table C3 shows the recapture factors used in a recent study. These recapture factors have been adapted in this Port Shutdown impact study.	
Export and Import Substitution	We assume goods originally scheduled for export from Port Arthur can instead be diverted to U.S. importers of these goods. However, this adjustment is affected by the Port Substitution adjustment for both U.S. exports and imports into the U.S.	

Table 3. Impact analysis of import disruption of crude oil for the Port Arthur MSA (base case with no resilience adjustment).

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (net double-counting) ($M)	% Output Impacts
		1	2	3 (=1/2)	4	5	6 (=1/5)	7	8 (=4+7-1)	
1	Agriculture, forestry and fishing	0.0	1.030	0.0	1.8	1.030	0.0	0.3	2.0	3.9%
2	Coal mining	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.1	3.3%
4	Support activities for oil and gas operations	0.0	1.007	0.0	1.1	1.007	0.0	1.6	2.7	3.8%
5	Oil and gas extraction and other mining	0.0	1.001	0.0	0.6	1.001	0.0	22.3	23.0	43.9%
6	Electric power generation, transmission, and distribution	0.0	1.008	0.0	1.7	1.006	0.0	15.2	16.9	10.7%
7	Natural gas distribution	0.0	1.000	0.0	0.1	1.000	0.0	2.5	2.6	17.2%
8	Water, sewage and other systems	0.0	1.000	0.0	0.0	1.000	0.0	0.1	0.1	6.7%
9	Construction	0.0	1.006	0.0	22.4	1.005	0.0	7.4	29.8	3.6%
10	Food, beverage, and tobacco mfg	0.0	1.037	0.0	0.6	1.037	0.0	1.7	2.4	3.5%
11	Textile and mills, apparel and leather product	0.0	1.009	0.0	0.1	1.009	0.0	0.1	0.2	3.2%
12	Wood product mfg	0.0	1.108	0.0	0.4	1.108	0.0	0.4	0.8	2.3%
13	All other miscellaneous wood product mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
14	Pulp mills	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
15	Paperboard container and coated paper mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	1.4%
16	Other paper and printing	0.0	1.020	0.0	1.9	1.020	0.0	0.8	2.7	2.5%
17	Petroleum refineries	4,280.8	1.068	4,006.5	4,280.8	1.068	4,007.9	4,280.8	4,280.8	48.8%
18	Petroleum lubricating oil and grease mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
19	All other petroleum and coal products mfg	0.0	1.003	0.0	1.7	1.003	0.0	2.0	3.7	39.8%
20	Petrochemical mfg	0.0	1.252	0.0	202.1	1.251	0.0	15.0	217.2	13.0%
21	Alkalies and chlorine mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
22	Other basic organic chemical mfg	0.0	1.095	0.0	70.9	1.095	0.0	6.2	77.1	13.3%
23	Synthetic rubber mfg	0.0	1.001	0.0	20.9	1.001	0.0	0.3	21.2	10.5%
24	Fertilizer mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
25	Other chemical mfg	0.0	1.030	0.0	22.9	1.030	0.0	2.1	25.0	4.5%
26	Plastics and rubber products mfg	0.0	1.015	0.0	0.5	1.015	0.0	0.8	1.3	5.3%

Table 3. Impact analysis of import disruption of crude oil for the Port Arthur MSA (Base Case with No Resilience Adjustment) (Continued).

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (net double-counting) ($M)	% Output Impacts
27	Lime and gypsum product mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
28	Ground or treated mineral and earth mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
29	Other nonmetallic mineral product mfg	0.0	1.000	0.0	0.3	1.000	0.0	0.0	0.4	1.5%
30	Iron and steel mills and ferroalloy mfg	0.0	1.028	0.0	2.2	1.028	0.0	0.2	2.4	1.3%
31	Other primary metal and fabricated metal product mfg	0.0	1.013	0.0	3.2	1.013	0.0	0.6	3.7	1.1%
32	Motor vehicle mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0%
33	Other machinery and equipment mfg	0.0	1.212	0.0	3.7	1.209	0.0	8.7	12.4	3.3%
34	Miscellaneous mfg	0.0	1.009	0.0	0.1	1.009	0.0	0.4	0.6	4.4%
35	Wholesale trade	0.0	1.039	0.0	3.8	1.034	0.0	22.8	26.5	10.3%
36	Retail trade	0.0	1.091	0.0	4.6	1.068	0.0	22.9	27.5	6.9%
37	Air transportation	0.0	1.000	0.0	0.2	1.000	0.0	0.1	0.3	19.2%
38	Rail transportation	0.0	1.004	0.0	1.7	1.004	0.0	2.3	4.0	9.2%
39	Water transportation	0.0	1.001	0.0	0.2	1.001	0.0	2.3	2.5	11.3%
40	Truck transportation	0.0	1.025	0.0	3.8	1.024	0.0	4.0	7.8	15.7%
41	Other transportation	0.0	1.021	0.0	1.6	1.019	0.0	4.1	5.7	10.2%
42	Pipeline transportation	0.0	1.002	0.0	5.6	1.002	0.0	23.9	29.5	53.8%
43	Information and Communication	0.0	1.156	0.0	1.8	1.153	0.0	8.2	10.0	4.8%
44	Finance, insurance, real estate, and leasing	0.0	1.123	0.0	2.2	1.113	0.0	18.4	20.6	6.7%
45	Imputed rental for owner-occupied dwellings	0.0	1.011	0.0	0.7	1.008	0.0	19.2	19.9	6.1%
46	Waste management and remediation services	0.0	1.088	0.0	1.3	1.087	0.0	1.6	2.8	4.3%
47	Other business services	0.0	1.176	0.0	11.7	1.160	0.0	50.0	61.7	8.5%
48	Health, education & social services	0.0	1.116	0.0	6.0	1.087	0.0	19.3	25.3	5.6%
49	Accommodations, food services, and amusements	0.0	1.059	0.0	2.6	1.049	0.0	14.1	16.8	7.9%
50	Personal services	0.0	1.020	0.0	0.6	1.017	0.0	2.9	3.5	6.8%
51	Government and Non-NAICS	0.0	1.033	0.0	8.5	1.025	0.0	9.1	17.6	3.9%
	Total	4,280.8		4,006.5	4,697.2		4,007.9	4,594.6	5,011.1	28.1%

Table 4. Regional economic impacts of a 3-month disruption of crude oil supplies through ports of Port Arthur and Beaumont.

(in million 2008 dollars)

Case	Direct Output Loss (1)	Direct Value-Added Change (2)	Final Demand Impacts (3)	Total Supply Impacts (4)	Total Demand Impacts (5)	Total Net S+D Impacts (6=4+5-1)	Total Net S+D Impacts (%)
A. Crude Oil Disruption No Resilience	$4,281	$4,007	$4,008	$4,697	$4,594	$5,011	28.1%
B. With Re-routing	Re-routing has no effect on the impacts of crude oil disruption to the Port Region since we assume the re-routed crude oil will not be transported back to the Port Region.						
C. With SPR (($4.16 million barrels)	$3,877	$3,629	$3,630	$4,255	$4,162	$4,539	25.4%
D. With Use of Oil Inventories (12.2% of 3-month supply plus constraints on additives)	$3,511	$3,287	$3,288	$3,853	$3,769	$4,111	23.0%
E. With Export Diversion ($1.6 billion of Crude Oil)	$3,765	$3,524	$3,525	$4,132	$4,042	$4,408	24.7%
F. With Conservation (2%)	$4,195	$3,926	$3,928	$4,603	$4,503	$4,911	27.5%
G. With Production Rescheduling (all sectors; 49% in Petroleum Refining)	a	a	a	a	a	$2,602	14.6%
H. With All Resilience Adjustments	b	b	b	b	b	$1,785	10.0%

[a] This resilience adjustment is applied to the Total Supply + Demand Impacts.
[b] Total is non-additive of B, C, D, E, F, G to adjust for overlaps.

Table 5. Percentage input disruption of major import using sectors for a 3-month port closure.

Disrupted Import Commodity	Major Using Sector	Import Disruption to the Major Using Sector (million $)	Total Input of this Commodity Used in the Sector (million $)	% Input Disruption
3 Sand, gravel, clay and ceramic and refractory minerals	17. Petroleum refineries	1.57	6.66	23.6%
	09. Construction	0.26	1.08	23.5%
5 Oil and gas extraction and all other mining	17. Petroleum refineries	3,311.51	6,791.01	48.8%
10 Food, beverage, and tobacco mfg	10. Food, beverage, and tobacco mfg	0.86	13.98	6.1%
	48. Health, education & social services	0.34	5.50	6.1%
	49. Accommodations, food services, and amusements	0.95	15.46	6.1%
14 Pulp mills	Sector 14 is not in the Port Arthur and Beaumont Region I-O table (no commodities of sector 14 either from local or import are used in the Region production).			
16 Other paper and printing	16. Other paper and printing	0.13	18.78	0.7%
17 Petroleum refineries	17. Petroleum refineries	125.32	654.77	19.1%
	20. Petrochemical mfg	81.18	373.52	21.7%
	22. Other basic organic chemical mfg	29.14	138.73	21.0%
18 Petroleum lubricating oil and grease mfg	Sector 18 is not in the Port Arthur and Beaumont Region I-O table (no commodities of sector 18 either from local or import are used in the Region production).			
19 All other petroleum and coal products mfg	09. Construction	0.86	8.60	10.0%
	17. Petroleum refineries	2.73	24.08	11.3%
20 Petrochemical mfg	20. Petrochemical mfg	88.88	410.17	21.7%
	22. Other basic organic chemical mfg	30.62	120.70	25.4%
	25. Other chemical mfg	50.40	88.52	56.9%
21. Alkalies and chlorine mfg	Sector 21 is not in the Port Arthur and Beaumont Region I-O table (no commodities of sector 21 either from local or import are used in the Region production).			
22 Other basic organic chemical mfg	20. Petrochemical mfg	62.18	248.71	25.0%
	22. Other basic organic chemical mfg	17.54	66.78	26.3%
	25. Other chemical mfg	12.38	44.04	28.1%

Table 5. Percentage input disruption of major import using sectors for a 3-month port closure (Continued).

Disrupted Import Commodity	Major Using Sector	Import Disruption to the Major Using Sector (million $)	Total Input of this Commodity Used in the Sector (million $)	% Input Disruption
25 Other chemical mfg	20. Petrochemical mfg	15.83	21.06	75.2%
	22. Other basic organic chemical mfg	12.19	16.03	76.0%
	25. Other chemical mfg	38.35	53.27	72.0%
30. Iron and steel mills and ferroalloy mfg	30. Iron and steel mills and ferroalloy mfg	8.97	24.01	37.3%
	31. Other primary metal and fabricated metal mfg	13.12	34.77	37.7%
	33. Other machinery and equipment mfg	4.56	12.02	38.0%
31 Other primary metal and fabricated metal product mfg	09. Construction	7.33	47.94	15.3%
	31. Other primary metal and fabricated metal mfg	11.40	74.52	15.3%
	33. Other machinery and equipment mfg	5.71	37.97	15.0%
33 Other machinery and equipment mfg	09. Construction	12.11	50.62	23.9%
	33. Other machinery and equipment mfg	3.69	98.24	3.8%
51 Government and Non-NAICS	The imported commodities are all waste and scrap, which is under IMPLAN sector 434. From the IMPLAN 440-sector I-O table, sector 434 is not in the Port Arthur and Beaumont Region I-O table (no commodities of sector 434 either from local or import are used in the Region production).			

Table 6. Direct output losses of major import using sectors (after eliminating double-counting of multi-input disruptions).

I-O Model Sector	% Input Disruption	Annual Output (million $)	Output Losses for 3-Month Port Disruption (million $)
09. Construction	23.9%	3,346	200
10. Food, beverage, and tobacco mfg	6.1%	271	4
16. Other paper and printing	0.7%	429	1
17. Petroleum refineries	48.8%	35,115	4,281
20. Petrochemical mfg	75.2%	6,672	1,254
22. Other basic organic chemical mfg	76.0%	2,317	441
25. Other chemical mfg	72.0%	2,225	400
30. Iron and steel mills and ferroalloy mfg	37.3%	721	67
31. Other primary metal and fabricated metal mfg	37.7%	1,370	129
33. Other machinery and equipment mfg	38.0%	1,485	141
48. Health, education & social services	6.1%	1,825	28
49. Accommodations, food services, and amusements	6.1%	849	13

Table 7. Impact analysis of a 3-month import disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008.

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (net double-counting) ($M)	After Cap Total Import Output Disruption Impacts ($M)	% Output Impacts
		1	2	3 (=1/2)	4	5	6 (=1/5)	7	8 (=4+7-1)		
1	Agriculture, forestry and fishing	0.0	1.030	0.0	3.4	1.030	0.0	2.4	5.9	5.9	11%
2	Coal mining	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.000	0.0	0.1	1.000	0.0	0.0	0.1	0.1	7%
4	Support activities for oil and gas operations	0.0	1.007	0.0	3.9	1.007	0.0	1.8	5.7	5.7	8%
5	Oil and gas extraction and all other mining	0.0	1.001	0.0	2.4	1.001	0.0	25.1	27.5	27.5	52%
6	Electric power generation, transmission, and distribution	0.0	1.008	0.0	4.1	1.006	0.0	61.0	65.1	65.1	41%
7	Natural gas distribution	0.0	1.000	0.0	0.3	1.000	0.0	9.1	9.3	9.3	61%
8	Water, sewage and other systems	0.0	1.000	0.0	0.1	1.000	0.0	0.3	0.3	0.3	30%
9	Construction	200.0	1.006	198.9	258.1	1.005	199.1	219.7	277.7	277.7	33%
10	Food, beverage, and tobacco mfg	4.1	1.037	4.0	6.6	1.037	4.0	12.6	15.1	15.1	22%
11	Textile and mills, apparel and leather product	0.0	1.009	0.0	0.6	1.009	0.0	0.7	1.2	1.2	18%
12	Wood product mfg	0.0	1.108	0.0	1.4	1.108	0.0	6.1	7.5	7.5	22%
13	All other miscellaneous wood product mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
14	Pulp mills	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
15	Paperboard container and coated paper mfg	0.0	1.000	0.0	0.1	1.000	0.0	0.0	0.2	0.2	6%
16	Other paper and printing	0.8	1.020	0.7	7.9	1.020	0.7	5.1	12.2	12.2	11%
17	Petroleum refineries	4,280.8	1.068	4,006.5	4,332.0	1.068	4,007.9	4,704.7	4,755.9	4,755.9	54%
18	Petroleum lubricating oil and grease mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
19	All other petroleum and coal products mfg	0.0	1.003	0.0	2.0	1.003	0.0	3.5	5.4	5.4	59%
20	Petrochemical mfg	1,253.6	1.252	1,001.5	1,618.1	1.251	1,001.8	1,387.0	1,751.5	1,668.0	100%
21	Alkalies and chlorine mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
22	Other basic organic chemical mfg	440.5	1.095	402.2	593.7	1.095	402.3	596.0	749.2	579.3	100%
23	Synthetic rubber mfg	0.0	1.001	0.0	67.5	1.001	0.0	4.0	71.5	71.5	35%
24	Fertilizer mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
25	Other chemical mfg	400.5	1.030	388.7	482.2	1.030	388.8	414.6	496.3	496.3	89%
26	Plastics and rubber products mfg	0.0	1.015	0.0	3.3	1.015	0.0	9.5	12.8	12.8	51%

Table 7. Impact analysis of a 3-month import disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008 (Continued).

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (netdouble-counting) ($M)	After Cap Total Output Import Disruption Impacts ($M)	% Output Impacts
27	Lime and gypsum product mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
28	Ground or treated mineral and earth mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
29	Other nonmetallic mineral product mfg	0.0	1.000	0.0	1.3	1.000	0.0	0.1	1.4	1.4	6%
30	Iron and steel mills and ferroalloy mfg	67.3	1.028	65.5	75.5	1.028	65.5	71.7	79.9	79.9	44%
31	Other primary metal and fabricated metal product mfg	129.3	1.013	127.6	145.6	1.013	127.6	134.0	150.2	150.2	44%
32	Motor vehicle mfg	0.0	1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0	0%
33	Other machinery and equipment mfg	140.9	1.212	116.3	155.3	1.209	116.6	199.0	213.3	213.3	57%
34	Miscellaneous mfg	0.0	1.009	0.0	0.7	1.009	0.0	2.6	3.3	3.3	25%
35	Wholesale trade	0.0	1.039	0.0	10.9	1.034	0.0	96.2	107.0	107.0	42%
36	Retail trade	0.0	1.091	0.0	15.9	1.068	0.0	105.3	121.2	121.2	31%
37	Air transportation	0.0	1.000	0.0	0.3	1.000	0.0	0.4	0.7	0.7	42%
38	Rail transportation	0.0	1.004	0.0	3.2	1.004	0.0	15.5	18.7	18.7	43%
39	Water transportation	0.0	1.001	0.0	1.3	1.001	0.0	6.0	7.3	7.3	33%
40	Truck transportation	0.0	1.025	0.0	5.4	1.024	0.0	17.5	22.8	22.8	46%
41	Other transportation	0.0	1.021	0.0	3.4	1.019	0.0	14.1	17.6	17.6	32%
42	Pipeline transportation	0.0	1.002	0.0	7.3	1.002	0.0	28.1	35.5	35.5	65%
43	Information and Communication	0.0	1.156	0.0	7.9	1.153	0.0	40.6	48.5	48.5	23%
44	Finance, insurance, real estate, and leasing	0.0	1.123	0.0	8.4	1.113	0.0	85.1	93.5	93.5	30%
45	Imputed rental for owner-occupied dwellings	0.0	1.011	0.0	4.8	1.008	0.0	82.5	87.3	87.3	27%
46	Waste management and remediation services	0.0	1.088	0.0	3.7	1.087	0.0	6.4	10.0	10.0	15%
47	Other business services	0.0	1.176	0.0	38.6	1.160	0.0	254.8	293.4	293.4	41%
48	Health, education & social services	27.9	1.116	25.0	51.2	1.087	25.7	108.6	131.9	131.9	29%
49	Accommodations, food services, and amusements	13.0	1.059	12.3	21.0	1.049	12.4	67.9	75.9	75.9	36%
50	Personal services	0.0	1.020	0.0	2.3	1.017	0.0	12.5	14.8	14.8	29%
51	Government and Non-NAICS	0.0	1.033	0.0	26.5	1.025	0.0	44.5	71.0	71.0	16%
	Total	6,958.7		6,349.1	7,978.1		6,352.4	8,856.4	9,875.7	9,622.4	53.9%

Table 8. Regional economic impacts of a 3-month disruption of imports through Ports of Port Arthur and Beaumont.

(in million 2008 dollars)

Case	Direct Output Loss (1)	Direct Value-Added Change (2)	Final Demand Impacts (3)	Total Supply Impacts (4)	Total Demand Impacts (5)	Total After Cap Impacts[a] (6=4+5-1)	Total After Cap Impacts (%)
A. Base Case (No Resilience)	$6,959	$6,349	$6,352	$7,978	$8,856	$9,622	53.9%
B. With Re-routing	$4,549	$4,241	$4,242	$5,025	$5,021	$5,498	30.8%
C. With SPR	$6,555	$5,972	$5,975	$7,536	$8,423	$9,178	51.5%
D. With Use of Inventories	$4,958	$4,521	$4,523	$5,651	$6,065	$6,757	37.9%
E. With Export Diversion	$5,962	$5,454	$5,456	$6,811	$7,538	$8,372	46.9%
F. With Conservation	$6,820	$6,222	$6,225	$7,819	$8,679	$9.475	53.1%
G. With Production Rescheduling	b	b	b	b	b	$5,078	28.5%
H. With All Resilience Adjustments	c	c	c	c	c	$2,092	11.7%

[a] Total impacts equal total supply-side impacts plus total demand-side impacts, net the double-counting of direct output impacts. Also, for each sector, the total impacts are capped by its total gross output in the 3-month period.
[b] This resilience adjustment is applied to the Total Supply + Demand Impacts.
[c] Total is non-additive of B, C, D, E, F, G to adjust for overlaps.

Table 9. Final demand reduction resulting from export disruption.

(in million 2008 dollars)

I-O Model Sector	Export Data of the Two Ports		Export Data According to Port Region I-O Table		Final Demand Reduction	
	Domestic Export	Foreign Export	Domestic Export	Foreign Export	Domestic Export	Foreign Export
1. Agriculture, forestry and fishing	0	161	39	4	0	4
5 Oil and gas extraction and all other mining	405	0	4	2	4	0
10 Food, beverage, and tobacco mfg	61	0	30	4	30	0
12. Wood product mfg	0	1	8	2	0	1
14 Pulp mills	0	6	a			
16 Other paper and printing	0	3	93	1	0	1
17 Petroleum refineries	1,723	796	6,830	804	1,723	796
18 Petroleum lubricating oil and grease mfg	139	0	a			
20 Petrochemical mfg	156	0	1,043	110	156	0
21. Alkalies and chlorine mfg	4	96	a			
22. Other basic organic chemical mfg	378	186	140	191	140	186
24. Fertilizer mfg	0	33	a			
25 Other chemical mfg	54	36	455	50	54	36
30. Iron and steel mills and ferroalloy mfg	116	0	122	42	116	0
33 Other machinery and equipment mfg	0	4	2	69	0	4

[a] The Port region does not have sectors 14, 18, 21, and 24. These commodities could be produced in other regions and then transported to the two Ports to be delivered by ship. Therefore, export disruption of these commodities would not generate any demand-side multiplier impacts to the Port Region.

Table 10. Impact analysis of a 3-month export disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008.

	I-O Model Sector	Final Demand Impacts ($M)	Total Output Impacts ($M)	% Output Impacts	Final Demand Impacts After Export Diversion ($M)	Total Output Impacts After Export Diversion ($M)	% Output Impacts After Export Diversion
1	Agriculture, forestry and fishing	3.5	5.4	10%	3.5	4.6	9%
2	Coal mining	0.0	0.0	0%	0.0	0.0	0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	0.0	2%	0.0	0.0	1%
4	Support activities for oil and gas operations	0.0	1.5	2%	0.0	1.0	1%
5	Oil and gas extraction and all other mining	3.9	4.7	9%	0.0	0.5	1%
6	Electric power generation, transmission, and distribution	0.0	1.6	1%	0.0	0.8	1%
7	Natural gas distribution	0.0	0.1	1%	0.0	0.1	0%
8	Water, sewage and other systems	0.0	0.0	2%	0.0	0.0	1%
9	Construction	0.0	21.7	3%	0.0	11.5	1%
10	Food, beverage, and tobacco mfg	30.8	33.0	49%	27.9	29.6	44%
11	Textile and mills, apparel and leather product	0.0	0.2	3%	0.0	0.1	2%
12	Wood product mfg	0.5	1.1	3%	0.5	0.9	3%
13	All other miscellaneous wood product mfg	0.0	0.0	0%	0.0	0.0	0%
14	Pulp mills	0.0	0.0	0%	0.0	0.0	0%
15	Paperboard container and coated paper mfg	0.0	0.0	2%	0.0	0.0	1%
16	Other paper and printing	0.8	3.6	3%	0.8	2.5	2%
17	Petroleum refineries	2,519.0	2,709.9	31%	949.6	1,025.5	12%
18	Petroleum lubricating oil and grease mfg	0.0	0.0	0%	0.0	0.0	0%
19	All other petroleum and coal products mfg	0.0	1.2	13%	0.0	0.5	5%
20	Petrochemical mfg	156.0	442.8	27%	61.8	224.7	13%
21	Alkalies and chlorine mfg	0.0	0.0	0%	0.0	0.0	0%
22	Other basic organic chemical mfg	325.7	414.7	72%	270.0	318.7	55%
23	Synthetic rubber mfg	0.0	28.1	14%	0.0	15.1	8%
24	Fertilizer mfg	0.0	0.0	0%	0.0	0.0	0%
25	Other chemical mfg	90.2	131.8	24%	45.7	71.1	13%
26	Plastics and rubber products mfg	0.0	1.2	5%	0.0	0.7	3%

Table 10. Impact analysis of a 3-month export disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008 (Continued).

	I-O Model Sector	Final Demand Impacts ($M)	Total Output Impacts ($M)	% Output Impacts	Final Demand Impacts After Export Diversion ($M)	Total Output Impacts After Export Diversion ($M)	% Output Impacts After Export Diversion
27	Lime and gypsum product mfg	0.0	0.0	0%	0.0	0.0	0%
28	Ground or treated mineral and earth mfg	0.0	0.0	0%	0.0	0.0	0%
29	Other nonmetallic mineral product mfg	0.0	0.5	2%	0.0	0.3	1%
30	Iron and steel mills and ferroalloy mfg	115.7	121.4	67%	115.7	120.3	67%
31	Other primary metal and fabricated metal product mfg	0.0	8.8	3%	0.0	7.0	2%
32	Motor vehicle mfg	0.0	0.0	0%	0.0	0.0	0%
33	Other machinery and equipment mfg	4.4	12.2	3%	4.4	10.1	3%
34	Miscellaneous mfg	0.0	0.3	2%	0.0	0.2	1%
35	Wholesale trade	0.0	4.2	2%	0.0	2.3	1%
36	Retail trade	0.0	5.8	1%	0.0	3.4	1%
37	Air transportation	0.0	0.2	9%	0.0	0.1	4%
38	Rail transportation	0.0	1.3	3%	0.0	0.6	1%
39	Water transportation	0.0	0.3	1%	0.0	0.2	1%
40	Truck transportation	0.0	2.8	6%	0.0	1.2	2%
41	Other transportation	0.0	1.5	3%	0.0	0.8	1%
42	Pipeline transportation	0.0	3.8	7%	0.0	1.6	3%
43	Information and Communication	0.0	2.3	1%	0.0	1.3	1%
44	Finance, insurance, real estate, and leasing	0.0	2.9	1%	0.0	1.8	1%
45	Imputed rental for owner-occupied dwellings	0.0	0.8	0%	0.0	0.5	0%
46	Waste management and remediation services	0.0	1.3	2%	0.0	0.7	1%
47	Other business services	0.0	13.9	2%	0.0	8.0	1%
48	Health, education & social services	0.0	9.6	2%	0.0	5.9	1%
49	Accommodations, food services, and amusements	0.0	4.5	2%	0.0	3.0	1%
50	Personal services	0.0	0.8	2%	0.0	0.5	1%
51	Government and Non-NAICS	0.0	10.1	2%	0.0	5.9	1%
	Total	3,250.6	4,012	22.5%	1,480.1	1,883.7	10.6%

Table 11. Impact analysis of a 3-month disruption of Port On-Site Operation for the Port MSA region, 2008.

	I-O Model Sector	Direct Revenue Losses of Port On-Site Operations ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Demand-Side Output Impacts of Disrupted Port On-Site Operations ($M)
1	Agriculture, forestry and fishing	0.0	1.030	0.0	0.0
2	Coal mining	0.0	1.000	0.0	0.0
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.000	0.0	0.0
4	Support activities for oil and gas operations	0.0	1.007	0.0	0.0
5	Oil and gas extraction and all other mining	0.0	1.001	0.0	0.0
6	Electric power generation, transmission, and distribution	0.0	1.006	0.0	0.5
7	Natural gas distribution	0.0	1.000	0.0	0.0
8	Water, sewage and other systems	0.0	1.000	0.0	0.0
9	Construction	0.0	1.005	0.0	0.2
10	Food, beverage, and tobacco mfg	0.0	1.037	0.0	0.2
11	Textile and mills, apparel and leather product	0.0	1.009	0.0	0.0
12	Wood product mfg	0.0	1.108	0.0	0.0
13	All other miscellaneous wood product mfg	0.0	1.000	0.0	0.0
14	Pulp mills	0.0	1.000	0.0	0.0
15	Paperboard container and coated paper mfg	0.0	1.000	0.0	0.0
16	Other paper and printing	0.0	1.020	0.0	0.0
17	Petroleum refineries	0.0	1.068	0.0	1.6
18	Petroleum lubricating oil and grease mfg	0.0	1.000	0.0	0.0
19	All other petroleum and coal products mfg	0.0	1.003	0.0	0.0
20	Petrochemical mfg	0.0	1.251	0.0	0.2
21	Alkalies and chlorine mfg	0.0	1.000	0.0	0.0
22	Other basic organic chemical mfg	0.0	1.095	0.0	0.1
23	Synthetic rubber mfg	0.0	1.001	0.0	0.0
24	Fertilizer mfg	0.0	1.000	0.0	0.0
25	Other chemical mfg	0.0	1.030	0.0	0.1
26	Plastics and rubber products mfg	0.0	1.015	0.0	0.1
27	Lime and gypsum product mfg	0.0	1.000	0.0	0.0

Table 11. Impact analysis of a 3-month disruption of Port On-Site Operation for the Port MSA region, 2008 (Continued).

	I-O Model Sector	Direct Revenue Losses of Port On-Site Operations ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Demand-Side Output Impacts of Disrupted Port On-Site Operations ($M)
28	Ground or treated mineral and earth mfg	0.0	1.000	0.0	0.0
29	Other nonmetallic mineral product mfg	0.0	1.000	0.0	0.0
30	Iron and steel mills and ferroalloy mfg	0.0	1.028	0.0	0.0
31	Other primary metal and fabricated metal product mfg	0.0	1.013	0.0	0.0
32	Motor vehicle mfg	0.0	1.000	0.0	0.0
33	Other machinery and equipment mfg	0.0	1.209	0.0	0.7
34	Miscellaneous mfg	0.0	1.009	0.0	0.0
35	Wholesale trade	0.0	1.034	0.0	0.6
36	Retail trade	0.0	1.068	0.0	2.2
37	Air transportation	0.0	1.000	0.0	0.0
38	Rail transportation	0.0	1.004	0.0	0.0
39	Water transportation	0.0	1.001	0.0	0.0
40	Truck transportation	0.0	1.024	0.0	0.1
41	Other transportation	28.1	1.019	27.6	28.1
42	Pipeline transportation	0.0	1.002	0.0	0.0
43	Information and Communication	0.0	1.153	0.0	0.6
44	Finance, insurance, real estate, and leasing	0.0	1.113	0.0	1.6
45	Imputed rental for owner-occupied dwellings	0.0	1.008	0.0	2.3
46	Waste management and remediation services	0.0	1.087	0.0	0.1
47	Other business services	0.0	1.160	0.0	2.0
48	Health, education & social services	0.0	1.087	0.0	2.3
49	Accommodations, food services, and amusements	0.0	1.049	0.0	1.2
50	Personal services	0.0	1.017	0.0	0.3
51	Government and Non-NAICS	0.0	1.025	0.0	0.7
	Total	28.1		27.6	46.0

Table 12. Total output impacts of a 3-month disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008.

		Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions ($M)	After Cap Total Impacts ($M)	% Output Impacts	Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
1	Agriculture, forestry and fishing	11.3	11.3	22%	5.6	11%
2	Coal mining	0.0	0.0	0%	0.0	0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.1	0.1	9%	0.0	2%
4	Support activities for oil and gas operations	7.2	7.2	10%	2.1	3%
5	Oil and gas extraction and all other mining	32.2	32.2	61%	9.9	19%
6	Electric power generation, transmission, and distribution	67.2	67.2	43%	9.9	6%
7	Natural gas distribution	9.5	9.5	62%	1.4	9%
8	Water, sewage and other systems	0.3	0.3	32%	0.0	4%
9	Construction	299.5	299.5	36%	24.3	3%
10	Food, beverage, and tobacco mfg	48.3	48.3	71%	30.8	45%
11	Textile and mills, apparel and leather product	1.4	1.4	20%	0.2	3%
12	Wood product mfg	8.6	8.6	25%	1.3	4%
13	All other miscellaneous wood product mfg	0.0	0.0	0%	0.0	0%
14	Pulp mills	0.0	0.0	0%	0.0	0%
15	Paperboard container and coated paper mfg	0.2	0.2	8%	0.0	1%
16	Other paper and printing	15.8	15.8	15%	3.6	3%
17	Petroleum refineries	7,467.3	7,467.3	85%	2,782.1	32%
18	Petroleum lubricating oil and grease mfg	0.0	0.0	0%	0.0	0%
19	All other petroleum and coal products mfg	6.6	6.6	71%	2.0	21%
20	Petrochemical mfg	2,194.5	1,668.0	100%	313.9	19%
21	Alkalies and chlorine mfg	0.0	0.0	0%	0.0	0%
22	Other basic organic chemical mfg	1,163.9	579.3	100%	350.4	60%
23	Synthetic rubber mfg	99.6	99.6	49%	23.9	12%
24	Fertilizer mfg	0.0	0.0	0%	0.0	0%
25	Other chemical mfg	628.3	556.2	100%	81.4	15%
26	Plastics and rubber products mfg	14.0	14.0	56%	1.3	5%

Table 12. Total output impacts of a 3-month disruption of ports of Port Arthur and Beaumont for the Port MSA region, 2008 (Continued).

		Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions ($M)	After Cap Total Impacts ($M)	% Output Impacts	Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
27	Lime and gypsum product mfg	0.0	0.0	0%	0.0	0%
28	Ground or treated mineral and earth mfg	0.0	0.0	0%	0.0	0%
29	Other nonmetallic mineral product mfg	1.9	1.9	8%	0.5	2%
30	Iron and steel mills and ferroalloy mfg	201.3	180.2	100%	121.3	67%
31	Other primary metal and fabricated metal product mfg	159.0	159.0	46%	8.6	3%
32	Motor vehicle mfg	0.0	0.0	0%	0.0	0%
33	Other machinery and equipment mfg	226.3	226.3	61%	15.9	4%
34	Miscellaneous mfg	3.6	3.6	27%	0.5	3%
35	Wholesale trade	111.8	111.8	43%	15.0	6%
36	Retail trade	129.2	129.2	33%	18.1	5%
37	Air transportation	0.8	0.8	52%	0.3	17%
38	Rail transportation	20.1	20.1	46%	3.4	8%
39	Water transportation	7.6	7.6	34%	1.9	9%
40	Truck transportation	25.7	25.7	52%	6.7	13%
41	Other transportation	47.2	47.2	85%	32.8	59%
42	Pipeline transportation	39.3	39.3	72%	21.7	40%
43	Information and Communication	51.4	51.4	25%	6.3	3%
44	Finance, insurance, real estate, and leasing	98.1	98.1	32%	12.5	4%
45	Imputed rental for owner-occupied dwellings	90.5	90.5	28%	18.8	6%
46	Waste management and remediation services	11.5	11.5	17%	2.1	3%
47	Other business services	309.3	309.3	43%	37.3	5%
48	Health, education & social services	143.8	143.8	32%	22.5	5%
49	Accommodations, food services, and amusements	81.6	81.6	38%	13.6	6%
50	Personal services	16.0	16.0	31%	2.8	5%
51	Government and Non-NAICS	81.7	81.7	18%	15.0	3%
	Total	13,933.7	12,729.4	71%	4,021.7	23%

Table 13. Impact analysis of a 3-month import disruption of ports of Port Arthur and Beaumont for the U.S., 2008.

	I-O Model Sector	Direct Output Loss ($M)	Supply -Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand -Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (net double-counting) ($M)	% Output Impacts
		1	2	3 (=1/2)	4	5	6 (=1/5)	7	8 (=4+7-1)	
1	Agriculture, forestry and fishing	0.0	1.271	0.0	1,152.0	1.259	0.0	2,106.8	3,258.8	3%
2	Coal mining	0.0	1.064	0.0	64.7	1.063	0.0	73.7	138.5	2%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.012	0.0	23.9	1.012	0.0	41.7	65.6	3%
4	Support activities for oil and gas operations	0.0	1.007	0.0	140.2	1.007	0.0	88.4	228.7	1%
5	Oil and gas extraction and all other mining	2,933.0	1.064	2,757.7	3,605.8	1.055	2,779.9	6,379.2	7,052.0	6%
6	Electric power generation, transmission, and distribution	0.0	1.021	0.0	522.5	1.013	0.0	920.0	1,442.4	2%
7	Natural gas distribution	0.0	1.009	0.0	348.5	1.007	0.0	415.6	764.1	3%
8	Water, sewage and other systems	0.0	1.001	0.0	24.7	1.001	0.0	18.3	43.0	2%
9	Construction	9,842.1	1.020	9,649.9	13,814.5	1.013	9,716.3	10,194.1	14,166.5	4%
10	Food, beverage, and tobacco mfg	6,073.1	1.366	4,446.3	7,908.6	1.325	4,585.1	7,444.3	9,279.9	4%
11	Textile and mills, apparel and leather product	0.0	1.105	0.0	310.3	1.100	0.0	215.1	525.4	2%
12	Wood product mfg	0.0	1.173	0.0	227.1	1.171	0.0	394.9	622.0	3%
13	All other miscellaneous wood product mfg	0.0	1.009	0.0	9.5	1.008	0.0	9.1	18.6	2%
14	Pulp mills	0.0	1.008	0.0	13.0	1.008	0.0	31.8	44.7	4%
15	Paperboard container and coated paper mfg	459.3	1.028	446.6	794.6	1.025	447.9	814.4	1,149.7	6%
16	Other paper and printing	1,374.3	1.141	1,204.9	1,966.0	1.133	1,213.3	2,029.3	2,621.0	4%
17	Petroleum refineries	5,691.2	1.089	5,228.1	7,820.1	1.080	5,268.3	7,377.4	9,506.2	6%
18	Petroleum lubricating oil and grease mfg	0.0	1.003	0.0	75.3	1.003	0.0	56.9	132.2	4%
19	All other petroleum and coal products mfg	0.0	1.010	0.0	154.1	1.010	0.0	146.1	300.2	4%
20	Petrochemical mfg	220.3	1.304	169.0	872.5	1.302	169.3	720.2	1,372.4	4%
21	Alkalies and chlorine mfg	0.0	1.008	0.0	38.7	1.008	0.0	28.5	67.2	3%
22	Other basic organic chemical mfg	151.1	1.094	138.1	660.1	1.092	138.3	452.6	961.7	4%
23	Synthetic rubber mfg	0.0	1.001	0.0	46.9	1.001	0.0	17.3	64.3	2%
24	Fertilizer mfg	0.0	1.186	0.0	84.6	1.186	0.0	80.2	164.8	3%
25	Other chemical mfg	1,849.9	1.282	1,443.2	3,806.5	1.261	1,467.5	3,346.2	5,302.8	3%
26	Plastics and rubber products mfg	52.9	1.057	50.1	700.2	1.052	50.3	651.9	1,299.2	2%
27	Lime and gypsum product mfg	0.0	1.003	0.0	26.9	1.003	0.0	35.7	62.6	3%

Table 13. Impact analysis of a 3-month import disruption of ports of Port Arthur and Beaumont for the U.S., 2008 (Continued).

	I-O Model Sector	Direct Output Loss ($M)	Supply -Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand -Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (net double-counting) ($M)	% Output Impacts
28	Ground or treated mineral and earth mfg	0.0	1.027	0.0	7.4	1.027	0.0	15.2	22.6	3%
29	Other nonmetallic mineral product mfg	67.0	1.121	59.7	395.4	1.119	59.9	670.3	998.7	3%
30	Iron and steel mills and ferroalloy mfg	27.6	1.092	25.3	303.9	1.091	25.3	255.4	531.8	2%
31	Other primary metal and fabricated metal product mfg	140.0	1.295	108.1	1,409.5	1.286	108.9	1,753.8	3,023.3	2%
32	Motor vehicle mfg	22.3	1.019	21.9	594.1	1.013	22.0	259.4	831.3	1%
33	Other machinery and equipment mfg	447.5	1.297	345.0	4,521.9	1.274	351.4	2,296.1	6,370.5	1%
34	Miscellaneous mfg	0.0	1.056	0.0	600.7	1.047	0.0	370.3	971.1	1%
35	Wholesale trade	0.0	1.141	0.0	2,494.9	1.098	0.0	2,808.1	5,303.0	2%
36	Retail trade	0.0	1.177	0.0	2,571.9	1.099	0.0	2,742.7	5,314.6	2%
37	Air transportation	358.2	1.012	354.1	989.8	1.007	355.8	572.4	1,203.9	3%
38	Rail transportation	0.0	1.008	0.0	167.4	1.007	0.0	233.2	400.6	2%
39	Water transportation	0.0	1.002	0.0	72.2	1.002	0.0	81.0	153.1	2%
40	Truck transportation	667.9	1.065	627.4	1,562.4	1.055	633.3	1,409.4	2,304.0	3%
41	Other transportation	0.0	1.047	0.0	558.1	1.038	0.0	526.1	1,084.2	2%
42	Pipeline transportation	0.0	1.007	0.0	135.4	1.006	0.0	174.2	309.6	4%
43	Information and Communication	3.5	1.454	2.4	2,933.6	1.403	2.5	2,676.6	5,606.7	2%
44	Finance, insurance, real estate, and leasing	0.0	1.572	0.0	5,151.8	1.434	0.0	7,357.8	12,509.6	2%
45	Imputed rental for owner-occupied dwellings	0.0	1.046	0.0	958.3	1.025	0.0	2,204.9	3,163.2	1%
46	Waste management and remediation services	0.0	1.116	0.0	170.3	1.113	0.0	141.3	311.6	2%
47	Other business services	6.6	1.464	4.5	7,337.0	1.342	4.9	7,097.5	14,428.0	2%
48	Health, education & social services	990.8	1.367	724.8	5,881.8	1.207	820.6	4,482.9	9,373.9	2%
49	Accommodations, food services, and amusements	32.6	1.164	28.0	2,718.7	1.105	29.6	2,019.1	4,705.2	2%
50	Personal services	0.0	1.039	0.0	412.8	1.027	0.0	400.8	813.6	2%
51	Government and Non-NAICS	0.0	1.080	0.0	5,278.1	1.046	0.0	1,104.9	6,382.9	1%
	Total	31,411.4		27,835.1	92,439.7		28,250.1	85,743.3	146,771.6	2.1%

Table 14. Economic impacts of a 3-month disruption of imports through ports of Port Arthur and Beaumont to U.S.
(in million 2008 dollars)

Case	Direct Output Loss (1)	Direct Value-Added Change (2)	Final Demand Impacts (3)	Total Supply Impacts (4)	Total Demand Impacts (5)	Total After Cap Impacts[a] (6=4+5-1)	Total After Cap Impacts (%)
A. Base Case (No Resilience)	$31,411	$27,835	$28,250	$92,440	$85,743	$146,772	2.1%
B. With Re-routing	$3,141	$2,784	$2,825	$9,244	$8,574	$14,677	0.2%
C. With SPR	$31,173	$27,616	$28,029	$91,540	$85,222	$145,589	2.1%
D. With Use of Inventories	$14,861	$12,997	$13,172	$47,146	$38,975	$71,260	1.0%
E. With Export Diversion	$10,436	$9,183	$9,349	$36,539	$25,954	$52,057	0.8%
F. With Conservation	$30,783	$27,278	$27,685	$90,591	$84,028	$143,836	2.1%
G. With Production Rescheduling	b	b	b	b	b	$84,403	1.2%
H. With All Resilience Adjustments	c	c	c	c	c	$35.12	0.0005%

[a] The total impacts equal total supply-side impacts plus total demand-side impacts, net the double-counting of direct output impacts. Also, for each sector, the total impacts are capped by the total gross output of this sector in the 3-month period.
[b] This resilience adjustment is applied to the Total Supply + Demand Impacts.
[c] Total is non-additive of B, C, D, E, F, G to adjust for overlaps.

Table 15. Impact analysis of a 3-month export disruption of ports of Port Arthur and Beaumont for the U.S., 2008.

	I-O Model Sector	Final Demand Impacts ($M)	Total Output Impacts ($M)	% Output Impacts	Final Demand Impacts After Export Diversion ($M)	Total Output Impacts After Export Diversion ($M)	% Output Impacts After Export Diversion
1	Agriculture, forestry and fishing	160.6	469.3	0.5%	160.6	319.6	0.3%
2	Coal mining	0.0	14.4	0.2%	0.0	5.9	0.1%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	4.7	0.2%	0.0	1.8	0.1%
4	Support activities for oil and gas operations	0.0	39.2	0.2%	0.0	17.9	0.1%
5	Oil and gas extraction and all other mining	404.9	593.7	0.5%	0.0	80.8	0.1%
6	Electric power generation, transmission, and distribution	0.0	102.8	0.1%	0.0	36.7	0.0%
7	Natural gas distribution	0.0	62.5	0.2%	0.0	14.6	0.0%
8	Water, sewage and other systems	0.0	4.1	0.2%	0.0	1.8	0.1%
9	Construction	0.0	959.4	0.3%	0.0	420.8	0.1%
10	Food, beverage, and tobacco mfg	61.9	662.4	0.3%	56.0	399.8	0.2%
11	Textile and mills, apparel and leather product	0.0	71.0	0.2%	0.0	35.9	0.1%
12	Wood product mfg	0.5	57.1	0.2%	0.5	31.1	0.1%
13	All other miscellaneous wood product mfg	0.0	2.0	0.2%	0.0	1.0	0.1%
14	Pulp mills	5.6	10.1	0.9%	2.3	5.0	0.4%
15	Paperboard container and coated paper mfg	0.0	47.5	0.2%	0.0	22.9	0.1%
16	Other paper and printing	3.4	153.8	0.3%	3.4	79.5	0.1%
17	Petroleum refineries	2,519.0	3,054.6	2.0%	949.6	1,072.3	0.7%
18	Petroleum lubricating oil and grease mfg	138.9	165.6	5.1%	53.0	62.8	1.9%
19	All other petroleum and coal products mfg	0.0	51.7	0.7%	0.0	19.0	0.3%
20	Petrochemical mfg	156.0	513.4	1.3%	61.8	241.7	0.6%
21	Alkalies and chlorine mfg	99.8	112.0	4.8%	99.8	104.8	4.5%
22	Other basic organic chemical mfg	563.8	801.5	3.0%	467.4	585.0	2.2%
23	Synthetic rubber mfg	0.0	20.5	0.8%	0.0	9.9	0.4%
24	Fertilizer mfg	33.4	60.4	0.9%	33.4	47.0	0.7%
25	Other chemical mfg	90.2	900.9	0.5%	45.7	485.1	0.3%
26	Plastics and rubber products mfg	0.0	182.5	0.3%	0.0	98.0	0.2%

Table 15. Impact analysis of a 3-month export disruption of ports of Port Arthur and Beaumont for the U.S., 2008 (Continued).

	I-O Model Sector	Final Demand Impacts ($M)	Total Output Impacts ($M)	% Output Impacts	Final Demand Impacts After Export Diversion ($M)	Total Output Impacts After Export Diversion ($M)	% Output Impacts After Export Diversion
27	Lime and gypsum product mfg	0.0	4.7	0.2%	0.0	1.8	0.1%
28	Ground or treated mineral and earth mfg	0.0	1.5	0.2%	0.0	0.6	0.1%
29	Other nonmetallic mineral product mfg	0.0	76.2	0.2%	0.0	38.4	0.1%
30	Iron and steel mills and ferroalloy mfg	115.7	183.1	0.6%	115.7	149.5	0.5%
31	Other primary metal and fabricated metal product mfg	0.0	303.8	0.2%	0.0	163.8	0.1%
32	Motor vehicle mfg	0.0	114.0	0.2%	0.0	56.5	0.1%
33	Other machinery and equipment mfg	4.4	885.8	0.2%	4.4	446.6	0.1%
34	Miscellaneous mfg	0.0	127.4	0.2%	0.0	63.1	0.1%
35	Wholesale trade	0.0	497.2	0.2%	0.0	221.8	0.1%
36	Retail trade	0.0	484.9	0.1%	0.0	220.5	0.1%
37	Air transportation	0.0	200.9	0.6%	0.0	74.4	0.2%
38	Rail transportation	0.0	40.8	0.2%	0.0	16.5	0.1%
39	Water transportation	0.0	14.3	0.1%	0.0	6.6	0.1%
40	Truck transportation	0.0	257.4	0.4%	0.0	100.0	0.1%
41	Other transportation	0.0	128.2	0.2%	0.0	53.8	0.1%
42	Pipeline transportation	0.0	37.3	0.4%	0.0	13.6	0.2%
43	Information and Communication	0.0	531.5	0.1%	0.0	243.9	0.1%
44	Finance, insurance, real estate, and leasing	0.0	934.3	0.1%	0.0	429.2	0.1%
45	Imputed rental for owner-occupied dwellings	0.0	139.7	0.0%	0.0	65.2	0.0%
46	Waste management and remediation services	0.0	37.0	0.2%	0.0	16.5	0.1%
47	Other business services	0.0	1,425.8	0.2%	0.0	646.0	0.1%
48	Health, education & social services	0.0	981.7	0.2%	0.0	467.5	0.1%
49	Accommodations, food services, and amusements	0.0	448.5	0.2%	0.0	212.1	0.1%
50	Personal services	0.0	79.4	0.1%	0.0	36.9	0.1%
51	Government and Non-NAICS	0.0	1,006.1	0.2%	0.0	452.4	0.1%
	Total	4,358.1	18,059	0.3%	2,053.8	8,398	0.1%

Table 16. Impact analysis of a 3-month disruption of Port On-Site Operation for the U.S., 2008.

	I-O Model Sector	Direct Revenue Losses of Port On-Site Operations ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Demand-Side Output Impacts of Disrupted Port On-Site Operations ($M)
1	Agriculture, forestry and fishing	0.0	1.259	0.0	0.7
2	Coal mining	0.0	1.063	0.0	0.0
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.012	0.0	0.0
4	Support activities for oil and gas operations	0.0	1.007	0.0	0.0
5	Oil and gas extraction and all other mining	0.0	1.055	0.0	1.1
6	Electric power generation, transmission, and distribution	0.0	1.013	0.0	0.8
7	Natural gas distribution	0.0	1.007	0.0	0.2
8	Water, sewage and other systems	0.0	1.001	0.0	0.0
9	Construction	0.0	1.013	0.0	0.3
10	Food, beverage, and tobacco mfg	0.0	1.325	0.0	1.9
11	Textile and mills, apparel and leather product	0.0	1.100	0.0	0.2
12	Wood product mfg	0.0	1.171	0.0	0.1
13	All other miscellaneous wood product mfg	0.0	1.008	0.0	0.0
14	Pulp mills	0.0	1.008	0.0	0.0
15	Paperboard container and coated paper mfg	0.0	1.025	0.0	0.1
16	Other paper and printing	0.0	1.133	0.0	0.4
17	Petroleum refineries	0.0	1.080	0.0	2.0
18	Petroleum lubricating oil and grease mfg	0.0	1.003	0.0	0.0
19	All other petroleum and coal products mfg	0.0	1.010	0.0	0.0
20	Petrochemical mfg	0.0	1.302	0.0	0.2
21	Alkalies and chlorine mfg	0.0	1.008	0.0	0.0
22	Other basic organic chemical mfg	0.0	1.092	0.0	0.1
23	Synthetic rubber mfg	0.0	1.001	0.0	0.0
24	Fertilizer mfg	0.0	1.186	0.0	0.0
25	Other chemical mfg	0.0	1.261	0.0	1.1
26	Plastics and rubber products mfg	0.0	1.052	0.0	0.3
27	Lime and gypsum product mfg	0.0	1.003	0.0	0.0

Table 16. Impact analysis of a 3-month disruption of Port On-Site Operation for the U.S., 2008 (Continued).

	I-O Model Sector	Direct Revenue Losses of Port On-Site Operations ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Demand-Side Output Impacts of Disrupted Port On-Site Operations ($M)
28	Ground or treated mineral and earth mfg	0.0	1.027	0.0	0.0
29	Other nonmetallic mineral product mfg	0.0	1.119	0.0	0.1
30	Iron and steel mills and ferroalloy mfg	0.0	1.091	0.0	0.1
31	Other primary metal and fabricated metal product mfg	0.0	1.286	0.0	0.6
32	Motor vehicle mfg	0.0	1.013	0.0	0.3
33	Other machinery and equipment mfg	0.0	1.274	0.0	1.4
34	Miscellaneous mfg	0.0	1.047	0.0	0.3
35	Wholesale trade	0.0	1.098	0.0	1.8
36	Retail trade	0.0	1.099	0.0	2.9
37	Air transportation	0.0	1.007	0.0	0.2
38	Rail transportation	0.0	1.007	0.0	0.1
39	Water transportation	0.0	1.002	0.0	0.0
40	Truck transportation	0.0	1.055	0.0	0.4
41	Other transportation	28.1	1.038	27.1	28.1
42	Pipeline transportation	0.0	1.006	0.0	0.1
43	Information and Communication	0.0	1.403	0.0	2.5
44	Finance, insurance, real estate, and leasing	0.0	1.434	0.0	7.4
45	Imputed rental for owner-occupied dwellings	0.0	1.025	0.0	2.8
46	Waste management and remediation services	0.0	1.113	0.0	0.2
47	Other business services	0.0	1.342	0.0	5.3
48	Health, education & social services	0.0	1.207	0.0	4.5
49	Accommodations, food services, and amusements	0.0	1.105	0.0	2.3
50	Personal services	0.0	1.027	0.0	0.5
51	Government and Non-NAICS	0.0	1.046	0.0	1.2
	Total	28.1		27.6	73.2

Table 17. Total output impacts of a 3-month disruption of ports of Port Arthur and Beaumont for the U.S., 2008.

		Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
1	Agriculture, forestry and fishing	3,728.8	3.6%	320.7	0.3%
2	Coal mining	152.9	1.9%	5.9	0.1%
3	Sand, gravel, clay and ceramic and refractory minerals	70.4	3.0%	1.9	0.1%
4	Support activities for oil and gas operations	267.9	1.6%	18.0	0.1%
5	Oil and gas extraction and all other mining	7,646.8	6.8%	82.3	0.1%
6	Electric power generation, transmission, and distribution	1,546.0	1.8%	37.8	0.0%
7	Natural gas distribution	826.7	2.8%	14.9	0.0%
8	Water, sewage and other systems	47.1	1.8%	1.9	0.1%
9	Construction	15,126.3	4.0%	422.4	0.1%
10	Food, beverage, and tobacco mfg	9,944.2	4.3%	402.6	0.2%
11	Textile and mills, apparel and leather product	596.6	2.0%	36.2	0.1%
12	Wood product mfg	679.2	2.9%	31.2	0.1%
13	All other miscellaneous wood product mfg	20.6	1.9%	1.0	0.1%
14	Pulp mills	54.8	4.7%	5.0	0.4%
15	Paperboard container and coated paper mfg	1,197.4	5.9%	23.2	0.1%
16	Other paper and printing	2,775.1	4.6%	80.1	0.1%
17	Petroleum refineries	12,562.8	8.3%	1,074.7	0.7%
18	Petroleum lubricating oil and grease mfg	297.8	9.1%	62.9	1.9%
19	All other petroleum and coal products mfg	351.9	4.7%	19.0	0.3%
20	Petrochemical mfg	1,886.0	4.8%	242.1	0.6%
21	Alkalies and chlorine mfg	179.3	7.7%	104.8	4.5%
22	Other basic organic chemical mfg	1,763.3	6.6%	585.2	2.2%
23	Synthetic rubber mfg	84.7	3.3%	9.9	0.4%
24	Fertilizer mfg	225.3	3.5%	47.0	0.7%
25	Other chemical mfg	6,204.8	3.3%	486.9	0.3%
26	Plastics and rubber products mfg	1,482.0	2.8%	98.5	0.2%

Table 17. Total output impacts of a 3-month disruption of ports of Port Arthur and Beaumont for the U.S., 2008 (Continued).

		Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, Exports, Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
27	Lime and gypsum product mfg	67.3	3.1%	1.8	0.1%
28	Ground or treated mineral and earth mfg	24.1	2.8%	0.6	0.1%
29	Other nonmetallic mineral product mfg	1,075.0	3.3%	38.9	0.1%
30	Iron and steel mills and ferroalloy mfg	714.9	2.4%	149.7	0.5%
31	Other primary metal and fabricated metal product mfg	3,327.7	2.2%	165.2	0.1%
32	Motor vehicle mfg	945.6	1.2%	57.0	0.1%
33	Other machinery and equipment mfg	7,257.7	1.5%	450.0	0.1%
34	Miscellaneous mfg	1,098.8	1.7%	63.7	0.1%
35	Wholesale trade	5,802.1	1.9%	224.9	0.1%
36	Retail trade	5,802.4	1.7%	224.8	0.1%
37	Air transportation	1,405.0	3.9%	74.9	0.2%
38	Rail transportation	441.5	2.6%	16.7	0.1%
39	Water transportation	167.5	1.7%	6.7	0.1%
40	Truck transportation	2,561.8	3.8%	100.9	0.2%
41	Other transportation	1,240.5	2.2%	82.3	0.1%
42	Pipeline transportation	347.0	4.0%	13.8	0.2%
43	Information and Communication	6,140.7	1.7%	248.0	0.1%
44	Finance, insurance, real estate, and leasing	13,451.3	1.6%	440.4	0.1%
45	Imputed rental for owner-occupied dwellings	3,305.7	1.1%	69.6	0.0%
46	Waste management and remediation services	348.7	1.8%	16.7	0.1%
47	Other business services	15,859.1	2.1%	655.1	0.1%
48	Health, education & social services	10,360.2	2.1%	479.1	0.1%
49	Accommodations, food services, and amusements	5,155.9	2.0%	215.9	0.1%
50	Personal services	893.6	1.7%	37.7	0.1%
51	Government and Non-NAICS	7,390.3	1.5%	455.7	0.1%
	Total	164,903.5	2.4%	8,506.1	0.1%

Table 18. Impact analysis of the Medium Consequence Scenario for the Port MSA region, 2008.

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (netdouble-counting) ($M)	After Cap Total Import Disruption Output Impacts ($M)	% Output Impacts
		1	2	3 (=1/2)	4	5	6 (=1/5)	7	8 (=4+7-1)		
1	Agriculture, forestry and fishing	0.0	1.0304	0.0	0.2	1.0303	0.0	0.0	0.2	0.2	8%
2	Coal mining	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.0001	0.0	0.0	1.0001	0.0	0.0	0.0	0.0	7%
4	Support activities for oil and gas operations	0.0	1.0069	0.0	0.1	1.0069	0.0	0.1	0.2	0.2	8%
5	Oil and gas extraction and all other mining	0.0	1.0005	0.0	0.1	1.0005	0.0	2.0	2.1	2.1	90%
6	Electric power generation, transmission, and distribution	0.0	1.0081	0.0	0.2	1.0060	0.0	1.4	1.5	1.5	22%
7	Natural gas distribution	0.0	1.0002	0.0	0.0	1.0002	0.0	0.2	0.2	0.2	35%
8	Water, sewage and other systems	0.0	1.0002	0.0	0.0	1.0001	0.0	0.0	0.0	0.0	14%
9	Construction	0.0	1.0058	0.0	2.0	1.0046	0.0	0.7	2.7	2.7	7%
10	Food, beverage, and tobacco mfg	0.0	1.0373	0.0	0.1	1.0365	0.0	0.2	0.2	0.2	7%
11	Textile and mills, apparel and leather product	0.0	1.0093	0.0	0.0	1.0092	0.0	0.0	0.0	0.0	7%
12	Wood product mfg	0.0	1.1085	0.0	0.0	1.1084	0.0	0.0	0.1	0.1	5%
13	All other miscellaneous wood product mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
14	Pulp mills	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
15	Paperboard container and coated paper mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	3%
16	Other paper and printing	0.0	1.0197	0.0	0.2	1.0196	0.0	0.1	0.2	0.2	5%
17	Petroleum refineries	384.8	1.0684	360.2	384.8	1.0681	360.3	384.8	384.8	384.8	100%
18	Petroleum lubricating oil and grease mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
19	All other petroleum and coal products mfg	0.0	1.0026	0.0	0.2	1.0026	0.0	0.2	0.3	0.3	82%
20	Petrochemical mfg	0.0	1.2517	0.0	18.2	1.2513	0.0	1.4	19.5	19.5	27%
21	Alkalies and chlorine mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
22	Other basic organic chemical mfg	0.0	1.0953	0.0	6.4	1.0951	0.0	0.6	6.9	6.9	27%
23	Synthetic rubber mfg	0.0	1.0012	0.0	1.9	1.0011	0.0	0.0	1.9	1.9	22%
24	Fertilizer mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
25	Other chemical mfg	0.0	1.0303	0.0	2.1	1.0299	0.0	0.2	2.2	2.2	9%
26	Plastics and rubber products mfg	0.0	1.0154	0.0	0.0	1.0152	0.0	0.1	0.1	0.1	11%

Table 18. Impact analysis of the Medium Consequence Scenario for the Port MSA region, 2008 (Continued).

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (netdouble-counting) ($M)	After Cap Total Import Disruption Output Impacts ($M)	% Output Impacts
27	Lime and gypsum product mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
28	Ground or treated mineral and earth mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
29	Other nonmetallic mineral product mfg	0.0	1.0001	0.0	0.0	1.0001	0.0	0.0	0.0	0.0	3%
30	Iron and steel mills and ferroalloy mfg	0.0	1.0283	0.0	0.2	1.0283	0.0	0.0	0.2	0.2	3%
31	Other primary metal and fabricated metal product mfg	0.0	1.0132	0.0	0.3	1.0130	0.0	0.1	0.3	0.3	2%
32	Motor vehicle mfg	0.0	1.0000	0.0	0.0	1.0000	0.0	0.0	0.0	0.0	0%
33	Other machinery and equipment mfg	0.0	1.2123	0.0	0.3	1.2090	0.0	0.8	1.1	1.1	7%
34	Miscellaneous mfg	0.0	1.0094	0.0	0.0	1.0090	0.0	0.0	0.1	0.1	9%
35	Wholesale trade	0.0	1.0386	0.0	0.3	1.0338	0.0	2.0	2.4	2.4	21%
36	Retail trade	0.0	1.0914	0.0	0.4	1.0677	0.0	2.1	2.5	2.5	14%
37	Air transportation	0.0	1.0002	0.0	0.0	1.0001	0.0	0.0	0.0	0.0	39%
38	Rail transportation	0.0	1.0037	0.0	0.2	1.0035	0.0	0.2	0.4	0.4	19%
39	Water transportation	0.0	1.0007	0.0	0.0	1.0006	0.0	0.2	0.2	0.2	23%
40	Truck transportation	0.0	1.0247	0.0	0.3	1.0238	0.0	0.4	0.7	0.7	32%
41	Other transportation	0.0	1.0207	0.0	0.1	1.0191	0.0	0.4	0.5	0.5	21%
42	Pipeline transportation	0.0	1.0023	0.0	0.5	1.0023	0.0	2.1	2.7	2.4	100%
43	Information and Communication	0.0	1.1561	0.0	0.2	1.1531	0.0	0.7	0.9	0.9	10%
44	Finance, insurance, real estate, and leasing	0.0	1.1234	0.0	0.2	1.1133	0.0	1.7	1.9	1.9	14%
45	Imputed rental for owner-occupied dwellings	0.0	1.0112	0.0	0.1	1.0082	0.0	1.7	1.8	1.8	13%
46	Waste management and remediation services	0.0	1.0876	0.0	0.1	1.0871	0.0	0.1	0.3	0.3	9%
47	Other business services	0.0	1.1764	0.0	1.1	1.1598	0.0	4.5	5.5	5.5	18%
48	Health, education & social services	0.0	1.1156	0.0	0.5	1.0867	0.0	1.7	2.3	2.3	11%
49	Accommodations, food services, and amusements	0.0	1.0593	0.0	0.2	1.0489	0.0	1.3	1.5	1.5	16%
50	Personal services	0.0	1.0203	0.0	0.1	1.0173	0.0	0.3	0.3	0.3	14%
51	Government and Non-NAICS	0.0	1.0334	0.0	0.8	1.0254	0.0	0.8	1.6	1.6	8%
	Total	384.8		360.2	422.3		360.3	413.0	450.5	450.2	57.6%

Table 19. Regional economic impacts of import disruption in the Medium Consequence Scenario.

(in million 2008 dollars)

Case	Direct Output Loss (1)	Direct Value-Added Change (2)	Final Demand Impacts (3)	Total Supply Impacts (4)	Total Demand Impacts (5)	Total After Cap Impacts[a] (6=4+5-1)	Total After Cap Impacts (%)
A. Base Case (No Resilience)	$384.8	$360.2	$360.3	$422.3	$413.0	$450.2	57.6%
B. Re-routing	Have zero impacts to Port Region output loss reduction						
C. With Use of Inventories	$153.9	$144.1	$144.1	$168.9	$165.2	$180.2	23.0%
D. With Export Diversion	Not applicable in the Medium Consequence Scenario						
E. With Conservation	$377.1	$353.0	$353.1	$413.8	$404.8	$441.3	56.4%
F. With Production Rescheduling	b	b	b	b	b	$233.7	29.9%
G. With All Resilience Adjustments	c	c	c	c	c	$91.7	11.7%

[a] Total impacts equal total supply-side impacts plus total demand-side impacts, net the double-counting of direct output impacts. Also, for each sector, the total impacts are capped by its total gross output in the 4-day period.
[b] This resilience adjustment is applied to the Total Supply + Demand Impacts.
[c] Total is non-additive of B, C, D, E, F to adjust for overlaps.

Table 20. Total output impacts of the Medium Consequence Scenario for the Port Region, 2008.

		Total Output Impacts of Imports and Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, and Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
1	Agriculture, forestry and fishing	0.18	8.1%	0.05	2.0%
2	Coal mining	0.00	0.0%	0.00	0.0%
3	Sand, gravel, clay and ceramic and refractory minerals	0.00	6.7%	0.00	1.3%
4	Support activities for oil and gas operations	0.24	7.8%	0.05	1.6%
5	Oil and gas extraction and all other mining	2.07	89.9%	0.41	18.0%
6	Electric power generation, transmission, and distribution	1.54	22.3%	0.40	5.7%
7	Natural gas distribution	0.24	35.4%	0.06	8.8%
8	Water, sewage and other systems	0.01	14.2%	0.00	3.4%
9	Construction	2.68	7.3%	0.56	1.5%
10	Food, beverage, and tobacco mfg	0.22	7.4%	0.05	1.7%
11	Textile and mills, apparel and leather product	0.02	6.9%	0.00	1.5%
12	Wood product mfg	0.07	4.8%	0.02	1.0%
13	All other miscellaneous wood product mfg	0.00	0.0%	0.00	0.0%
14	Pulp mills	0.00	0.0%	0.00	0.0%
15	Paperboard container and coated paper mfg	0.00	2.8%	0.00	0.6%
16	Other paper and printing	0.25	5.2%	0.05	1.1%
17	Petroleum refineries	384.82	100.0%	77.00	20.0%
18	Petroleum lubricating oil and grease mfg	0.00	0.0%	0.00	0.0%
19	All other petroleum and coal products mfg	0.33	81.6%	0.07	16.3%
20	Petrochemical mfg	19.53	26.7%	3.91	5.3%
21	Alkalies and chlorine mfg	0.00	0.0%	0.00	0.0%
22	Other basic organic chemical mfg	6.94	27.3%	1.39	5.5%
23	Synthetic rubber mfg	1.91	21.6%	0.38	4.3%
24	Fertilizer mfg	0.00	0.0%	0.00	0.0%
25	Other chemical mfg	2.25	9.2%	0.45	1.9%
26	Plastics and rubber products mfg	0.12	11.0%	0.03	2.4%

Table 20. Total output impacts of the Medium Consequence Scenario for the Port Region, 2008 (Continued).

		Total Output Impacts of Imports and Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, and Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
27	Lime and gypsum product mfg	0.00	0.0%	0.00	0.0%
28	Ground or treated mineral and earth mfg	0.00	0.0%	0.00	0.0%
29	Other nonmetallic mineral product mfg	0.03	3.0%	0.01	0.6%
30	Iron and steel mills and ferroalloy mfg	0.22	2.7%	0.04	0.6%
31	Other primary metal and fabricated metal product mfg	0.34	2.2%	0.07	0.5%
32	Motor vehicle mfg	0.00	0.0%	0.00	0.0%
33	Other machinery and equipment mfg	1.14	7.0%	0.25	1.6%
34	Miscellaneous mfg	0.05	9.3%	0.01	2.2%
35	Wholesale trade	2.41	21.3%	0.55	4.9%
36	Retail trade	2.57	14.8%	0.65	3.7%
37	Air transportation	0.03	39.7%	0.01	13.5%
38	Rail transportation	0.36	19.0%	0.12	6.4%
39	Water transportation	0.23	23.3%	0.08	7.9%
40	Truck transportation	0.71	32.5%	0.24	11.0%
41	Other transportation	1.74	71.6%	1.40	57.6%
42	Pipeline transportation	2.40	100.0%	0.88	36.8%
43	Information and Communication	0.92	10.1%	0.22	2.4%
44	Finance, insurance, real estate, and leasing	1.93	14.2%	0.47	3.5%
45	Imputed rental for owner-occupied dwellings	1.89	13.3%	0.80	5.6%
46	Waste management and remediation services	0.26	9.0%	0.06	2.1%
47	Other business services	5.63	17.8%	1.28	4.1%
48	Health, education & social services	2.38	11.9%	0.73	3.6%
49	Accommodations, food services, and amusements	1.56	16.8%	0.47	5.0%
50	Personal services	0.33	14.7%	0.10	4.5%
51	Government and Non-NAICS	1.61	8.1%	0.40	2.0%
	Total	452.2	57.8%	93.72	12.0%

Table 21. Impact analysis of the Medium Consequence Scenario for the U.S., 2008.

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (netdouble-counting) ($M)	After Cap Total Import Disruption Output Impacts ($M)	% Output Impacts
		1	2	3 (=1/2)	4	5	6 (=1/5)	7	8 (=4+7-1)		
1	Agriculture, forestry and fishing	0.0	1.2714	0.0	48.8	1.2587	0.0	7.3	56.0	56.0	1.2%
2	Coal mining	0.0	1.0639	0.0	2.0	1.0632	0.0	1.3	3.3	3.3	0.9%
3	Sand, gravel, clay and ceramic and refractory minerals	0.0	1.0119	0.0	0.7	1.0118	0.0	0.5	1.2	1.2	1.2%
4	Support activities for oil and gas operations	0.0	1.0072	0.0	5.0	1.0070	0.0	5.4	10.4	10.4	1.4%
5	Oil and gas extraction and all other mining	0.0	1.0636	0.0	25.8	1.0551	0.0	322.5	348.3	348.3	7.0%
6	Electric power generation, transmission, and distribution	0.0	1.0209	0.0	15.9	1.0125	0.0	12.9	28.8	28.8	0.8%
7	Natural gas distribution	0.0	1.0093	0.0	5.7	1.0067	0.0	8.7	14.3	14.3	1.1%
8	Water, sewage and other systems	0.0	1.0011	0.0	0.7	1.0006	0.0	0.2	0.9	0.9	0.8%
9	Construction	0.0	1.0199	0.0	171.2	1.0129	0.0	13.3	184.5	184.5	1.1%
10	Food, beverage, and tobacco mfg	0.0	1.3659	0.0	75.9	1.3245	0.0	18.7	94.6	94.6	0.9%
11	Textile and mills, apparel and leather product	0.0	1.1047	0.0	9.3	1.0998	0.0	2.1	11.5	11.5	0.9%
12	Wood product mfg	0.0	1.1730	0.0	8.1	1.1714	0.0	1.2	9.3	9.3	0.9%
13	All other miscellaneous wood product mfg	0.0	1.0086	0.0	0.3	1.0085	0.0	0.1	0.4	0.4	0.8%
14	Pulp mills	0.0	1.0079	0.0	0.5	1.0078	0.0	0.1	0.6	0.6	1.1%
15	Paperboard container and coated paper mfg	0.0	1.0285	0.0	7.1	1.0255	0.0	1.9	9.0	9.0	1.0%
16	Other paper and printing	0.0	1.1406	0.0	21.1	1.1327	0.0	4.8	25.9	25.9	1.0%
17	Petroleum refineries	753.0	1.0886	691.7	753.0	1.0803	697.0	753.0	753.0	753.0	11.3%
18	Petroleum lubricating oil and grease mfg	0.0	1.0033	0.0	5.9	1.0030	0.0	1.4	7.3	7.3	5.1%
19	All other petroleum and coal products mfg	0.0	1.0098	0.0	11.7	1.0095	0.0	1.9	13.5	13.5	4.1%
20	Petrochemical mfg	0.0	1.3042	0.0	47.7	1.3018	0.0	8.0	55.7	55.7	3.3%
21	Alkalies and chlorine mfg	0.0	1.0081	0.0	2.4	1.0080	0.0	0.3	2.7	2.7	2.6%
22	Other basic organic chemical mfg	0.0	1.0938	0.0	34.1	1.0922	0.0	3.3	37.4	37.4	3.2%
23	Synthetic rubber mfg	0.0	1.0014	0.0	2.8	1.0013	0.0	0.1	3.0	3.0	2.6%
24	Fertilizer mfg	0.0	1.1864	0.0	3.9	1.1861	0.0	0.3	4.3	4.3	1.5%
25	Other chemical mfg	0.0	1.2818	0.0	99.1	1.2606	0.0	16.3	115.5	115.5	1.4%
26	Plastics and rubber products mfg	0.0	1.0568	0.0	21.1	1.0517	0.0	4.3	25.4	25.4	1.1%

Table 21. Impact analysis of the Medium Consequence Scenario for the U.S., 2008 (Continued).

	I-O Model Sector	Direct Output Loss ($M)	Supply-Side bjj	Direct Value-Added Change ($M)	Total Supply-Side Output Impacts ($M)	Demand-Side bjj	Final Demand Impacts ($M)	Total Demand-Side Output Impacts ($M)	Total Import Disruption Output Impacts (netdouble-counting) ($M)	After Cap Total Import Disruption Output Impacts ($M)	% Output Impacts
27	Lime and gypsum product mfg	0.0	1.0028	0.0	0.7	1.0027	0.0	0.3	1.0	1.0	1.0%
28	Ground or treated mineral and earth mfg	0.0	1.0274	0.0	0.2	1.0274	0.0	0.4	0.6	0.6	1.7%
29	Other nonmetallic mineral product mfg	0.0	1.1213	0.0	10.3	1.1190	0.0	2.3	12.6	12.6	0.9%
30	Iron and steel mills and ferroalloy mfg	0.0	1.0925	0.0	8.7	1.0912	0.0	3.1	11.8	11.8	0.9%
31	Other primary metal and fabricated metal product mfg	0.0	1.2954	0.0	39.9	1.2861	0.0	13.5	53.4	53.4	0.8%
32	Motor vehicle mfg	0.0	1.0190	0.0	16.9	1.0127	0.0	2.8	19.7	19.7	0.6%
33	Other machinery and equipment mfg	0.0	1.2974	0.0	128.5	1.2737	0.0	17.9	146.3	146.3	0.7%
34	Miscellaneous mfg	0.0	1.0558	0.0	18.3	1.0471	0.0	3.5	21.8	21.8	0.8%
35	Wholesale trade	0.0	1.1405	0.0	86.3	1.0977	0.0	28.2	114.5	114.5	0.8%
36	Retail trade	0.0	1.1769	0.0	81.6	1.0986	0.0	28.9	110.5	110.5	0.8%
37	Air transportation	0.0	1.0117	0.0	45.5	1.0068	0.0	2.4	47.9	47.9	3.1%
38	Rail transportation	0.0	1.0082	0.0	8.4	1.0066	0.0	2.2	10.6	10.6	1.4%
39	Water transportation	0.0	1.0025	0.0	2.4	1.0016	0.0	1.0	3.4	3.4	0.8%
40	Truck transportation	0.0	1.0645	0.0	54.9	1.0547	0.0	6.8	61.7	61.7	2.1%
41	Other transportation	0.0	1.0470	0.0	24.9	1.0375	0.0	5.0	29.9	29.9	1.2%
42	Pipeline transportation	0.0	1.0069	0.0	7.9	1.0058	0.0	10.9	18.8	18.8	5.0%
43	Information and Communication	0.0	1.4542	0.0	88.6	1.4031	0.0	29.6	118.2	118.2	0.7%
44	Finance, insurance, real estate, and leasing	0.0	1.5716	0.0	155.5	1.4336	0.0	102.0	257.5	257.5	0.7%
45	Imputed rental for owner-occupied dwellings	0.0	1.0463	0.0	22.8	1.0252	0.0	26.5	49.3	49.3	0.4%
46	Waste management and remediation services	0.0	1.1159	0.0	6.6	1.1131	0.0	1.7	8.3	8.3	1.0%
47	Other business services	0.0	1.4637	0.0	243.8	1.3417	0.0	81.5	325.3	325.3	1.0%
48	Health, education & social services	0.0	1.3669	0.0	153.0	1.2075	0.0	43.8	196.8	196.8	0.9%
49	Accommodations, food services, and amusements	0.0	1.1641	0.0	72.2	1.1045	0.0	23.4	95.6	95.6	0.8%
50	Personal services	0.0	1.0391	0.0	12.8	1.0272	0.0	4.7	17.5	17.5	0.7%
51	Government and Non-NAICS	0.0	1.0800	0.0	169.4	1.0461	0.0	13.4	182.8	182.8	0.8%
	Total	753.0		691.7	2,840.0		697.0	1,645.4	3,732.4	3,732.4	1.2%

Table 22. U.S. economic impacts of import disruption in the Medium Consequence Scenario.

(in million 2008 dollars)

Case	Direct Output Loss (1)	Direct Value-Added Change (2)	Final Demand Impacts (3)	Total Supply Impacts (4)	Total Demand Impacts (5)	Total After Cap Impacts[a] (6=4+5-1)	Total After Cap Impacts (%)
A. Base Case (No Resilience)	$753.0	$691.7	$697.0	$2,840.0	$1,645.4	$3,732.4	1.2%
B. With Re-routing	$602.4	$553.4	$557.6	$2,272.0	$1,316.4	$2,985.9	1.0%
C. With Use of Inventories	$153.9	$141.4	$142.5	$580.5	$336.4	$763.0	0.3%
D. With Export Diversion	Not applicable in the Medium Consequence Scenario						
E. With Conservation	$738.0	$677.9	$683.1	$2,783.2	$1,612.5	$3,657.8	1.2%
F. With Production Rescheduling	b	b	b	b	b	$2,116.5	0.7%
G. With All Resilience Adjustments	c	c	c	c	c	$339.2	0.1%

[a] Total impacts equal total supply-side impacts plus total demand-side impacts, net the double-counting of direct output impacts. Also, for each sector, the total impacts are capped by its total gross output in the 4-day period.
[b] This resilience adjustment is applied to the Total Supply + Demand Impacts.
[c] Total is non-additive of B, C, D, E, F to adjust for overlaps.

Table 23. Total output impacts of the Medium Consequence Scenario for the U.S., 2008.

		Total Output Impacts of Imports and Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, and Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
1	Agriculture, forestry and fishing	56.1	1.2%	5.6	0.1%
2	Coal mining	3.3	0.9%	0.3	0.1%
3	Sand, gravel, clay and ceramic and refractory minerals	1.2	1.2%	0.1	0.1%
4	Support activities for oil and gas operations	10.4	1.4%	0.9	0.1%
5	Oil and gas extraction and all other mining	348.3	7.0%	28.5	0.6%
6	Electric power generation, transmission, and distribution	28.8	0.8%	2.9	0.1%
7	Natural gas distribution	14.4	1.1%	1.4	0.1%
8	Water, sewage and other systems	0.9	0.8%	0.1	0.1%
9	Construction	184.5	1.1%	15.5	0.1%
10	Food, beverage, and tobacco mfg	94.7	0.9%	7.8	0.1%
11	Textile and mills, apparel and leather product	11.5	0.9%	0.9	0.1%
12	Wood product mfg	9.3	0.9%	0.8	0.1%
13	All other miscellaneous wood product mfg	0.4	0.8%	0.0	0.1%
14	Pulp mills	0.6	1.1%	0.0	0.1%
15	Paperboard container and coated paper mfg	9.0	1.0%	0.7	0.1%
16	Other paper and printing	26.0	1.0%	2.1	0.1%
17	Petroleum refineries	753.1	11.3%	61.6	0.9%
18	Petroleum lubricating oil and grease mfg	7.3	5.1%	0.6	0.4%
19	All other petroleum and coal products mfg	13.5	4.1%	1.1	0.3%
20	Petrochemical mfg	55.7	3.3%	4.6	0.3%
21	Alkalies and chlorine mfg	2.7	2.6%	0.2	0.2%
22	Other basic organic chemical mfg	37.4	3.2%	3.1	0.3%
23	Synthetic rubber mfg	3.0	2.6%	0.2	0.2%
24	Fertilizer mfg	4.3	1.5%	0.3	0.1%
25	Other chemical mfg	115.5	1.4%	9.5	0.1%
26	Plastics and rubber products mfg	25.4	1.1%	2.1	0.1%

Table 23. Total output impacts of the Medium Consequence Scenario for the U.S., 2008 (Continued).

		Total Output Impacts of Imports and Port On-Site Operation Disruptions ($M)	% Output Impacts	Total Output Impacts of Imports, and Port On-Site Operation Disruptions (After Resilience Adjs) ($M)	% Output Impacts (After Resilience Adjs)
27	Lime and gypsum product mfg	1.0	1.0%	0.1	0.1%
28	Ground or treated mineral and earth mfg	0.6	1.7%	0.1	0.1%
29	Other nonmetallic mineral product mfg	12.6	0.9%	1.0	0.1%
30	Iron and steel mills and ferroalloy mfg	11.8	0.9%	1.0	0.1%
31	Other primary metal and fabricated metal product mfg	53.4	0.8%	4.4	0.1%
32	Motor vehicle mfg	19.7	0.6%	1.6	0.0%
33	Other machinery and equipment mfg	146.4	0.7%	12.0	0.1%
34	Miscellaneous mfg	21.8	0.8%	1.8	0.1%
35	Wholesale trade	114.6	0.8%	10.4	0.1%
36	Retail trade	110.6	0.8%	10.1	0.1%
37	Air transportation	47.9	3.1%	6.5	0.4%
38	Rail transportation	10.6	1.4%	1.4	0.2%
39	Water transportation	3.4	0.8%	0.5	0.1%
40	Truck transportation	61.7	2.1%	8.4	0.3%
41	Other transportation	31.1	1.3%	5.3	0.2%
42	Pipeline transportation	18.8	5.0%	2.6	0.7%
43	Information and Communication	118.3	0.7%	10.5	0.1%
44	Finance, insurance, real estate, and leasing	257.8	0.7%	23.0	0.1%
45	Imputed rental for owner-occupied dwellings	49.4	0.4%	8.0	0.1%
46	Waste management and remediation services	8.3	1.0%	0.7	0.1%
47	Other business services	325.5	1.0%	28.9	0.1%
48	Health, education & social services	197.0	0.9%	22.3	0.1%
49	Accommodations, food services, and amusements	95.7	0.8%	10.8	0.1%
50	Personal services	17.5	0.7%	2.0	0.1%
51	Government and Non-NAICS	182.9	0.8%	17.6	0.1%
	Total	3,735.6	1.2%	342.4	0.1%

14 ENDNOTES

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[1] Another major reason for the use of an I-O approach is the resource constraint of this study. The REMI Model would need to be leased for $25K. It would require at least that much to build a CGE model for the Port Arthur / Beaumont region as well.

[2] CGE models typically allow for substitution across inputs, but in most models this refers to substitution among primary factors and major aggregates, such as all materials as a whole. Even in these models, substitution possibilities are not included for ordinary material inputs.

[3] While resilience has the potential to significantly reduce the losses from lapses in maritime safety, there is a category of effects that can greatly exacerbate them. These have been characterized by Rose (2009) as behavioral linkages--changes in perceptions that amplify the risks and lead to behavior that incurs unwarranted losses. They often stem from the social amplification of risk by way of media coverage or rumor that translates into paralyzing fear (Kasperson et al., 1995), as well as from long-run stigma effects. For example, the major contributor to the economic losses from 9/11 was the subsequent nearly 2-year drop in airline travel and related tourism (Rose et al., 2009). These affects are most likely to manifest themselves from the use of an insidious threat like a radiological, chemical, or biological dispersion device, which pose difficult decontamination and risk communication problems (see, e.g., Giesecke et al., 2011). Since this is not the mechanism of attack for the port disruptions simulated in this paper, we have omitted this consideration.

[4] The crude oil import from U.S. sources is negligible compared with foreign imports of this commodity. The former is only about 0.67% of the latter.

[5] All dollar values are inflated to 2010 dollars using the Consumer Price Index.

[6] Euros are converted to dollars using the February 18, 2010 exchange rate.

[7] These include 6 ships restricted to the berths and 11 ships (80% of the remaining 14 ships) that were not diverted to the other ports.

[8] In response to Hurricane Katrina, in September 2005, President Bush issued a Finding of a Severe Energy Supply Interruption as defined in section 161(d) of the Energy Policy and Conservation Act (EPCA), 42 U.S.C. 6 241(d). This authorized and directed the Secretary of Energy, at his discretion, to drawdown and sell crude oil from the Strategic Petroleum Reserve. The total U.S. response to Hurricane Katrina, considering both the emergency loans of 9.8 million barrels and the 11 million barrels of oil that was sold, was 20.8 million barrels.

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APPENDIX A. GLOSSARY

Benefit transfer method: Adapting results from one context to another, with appropriate adjustments made for such factors as differences in population and economic size, location and other important features.

Double-counting: A situation where individual types of benefits or costs are inadvertently counted twice. This situation needs to be corrected in order to provide an accurate assessment.

Conservation: Utilizing less of a resource. When this is done at a lower cost, such as being able to produce the same level of output with a lower level of inputs, this is referred to as economic efficiency improvement.

Demand-driven input-output model: This is the standard version of the I-O model, where a change in final demand stimulates the economy by causing product supply to respond through a multiplier process.

Direct economic loss: An on-site effect on a major economic indicator such as assets (property) or economic activity (business interruption).

Export diversion: The re-routing of goods intended for export out of the country to use domestically instead to offset the disruption of import commodities.

Final Goods: Goods purchased by consumers, government expenditures on goods, and capital equipment and construction.

Gross output: The total revenue received from the sale of a good from a given sector. It includes all costs of production--both returns to primary factors of production (including a normal rate of return on investment) and payments for intermediate goods.

Harmonized System (HS): an internationally standardized naming and coding system to classify the trade commodities.

Impact Analysis for Planning (IMPLAN) System: A software system and data base that consists of economic data for every county of the U.S., a set of algorithms for translating the data into input-output tables for any county or county/state grouping, and a set of algorithms to perform economic analysis with the data and I-O tables.

Import Matrix: The table of data on the dollar values of goods of each type used in the production process of each sector or consumed by end users that are imported from outside a region (from both abroad or other regions in the country) or nation.

Indirect economic loss: Strictly speaking, this should refer to indirect business interruption, or the ripple effects of a shock. It is sometimes also used to refer to miscellaneous categories of impact such as environmental effects.

Input-output analysis: In its most basic form, a static, linear model of all purchases and sales between sectors of an economy, based on the technological relationships of production. The basic model can be modified to become dynamic, non-linear, include purchases and sales between sectors of different economies, and can be based on not only technology but prices and any other variables that can be quantified.

Intermediate Goods: Goods used to produce other goods. These are primarily "industrial" goods.

Inventory use: The accessing of inventories or stockpiles set aside to make up a shortfall under normal circumstances or in a crisis.

Metropolitan Statistical Area (MSA): A formal designation of the U.S. Census Bureau for contiguous counties that contain a core urban area with populations of at least 50,000.

NAICS: North American Industrial Classification System. This is an international system of classification for distinguishing sectors of an economy.

Output multiplier: The total (direct, indirect, and induced) output impacts divided by the direct output impacts of an external stimulus (positive or negative) to the economy.

Production recapture (rescheduling): The ability to make up lost production by working overtime or extra shifts following the disaster shock, during or after recovery, in order to recoup losses.

Refining additives: Specialty chemicals required in the petroleum refining process.

Resilience: In general the ability to absorb a shock, maintain function, and rebound quickly. Economic resilience refers to the ability to use resources as efficiently as possible and to invest wisely in recovery and reconstruction.

Ship diversion: The re-routing of ships headed to a damaged port to other ports.

Strategic Petroleum Reserve: A set aside of more than 700 million barrels of oil by the U.S. government for use in cases of emergency. Emergencies include war, embargos, natural disasters, and any other crises deemed worthy by the president of the United States.

Supply-driven input-output model: A variant of the standard I-O model in which the stimulus to the economy takes place through the production side of the economy. This can be a change in primary factors of individual sector economic activity and ripples throughout the economy through marketing patterns of sales of one sector to another.

Value-added: Returns to primary factors of production (labor, capital, and natural resources), that provide the basis for a net measure of economic activity. Essentially equivalent to Gross Domestic Product (GDP), or Gross Regional Product (GRP).

APPENDIX B. DATA SOURCES

WISERTrade Database:

Foreign import and export data for Port of Port Arthur and Port of Beaumont are obtained from the World Institute for Strategic Economic Research (WISER) Foreign Trade Database. The predecessor of WISER, MISER at the University of Massachusetts, was one of the first Business and Industry Data Centers chosen by the U.S. Census Bureau to provide U.S. and state level trade statistics (WISER, 2011). Since 2004, WISER also provides export and import data for 450 individual ports in the U.S. The foreign trade data we obtained from the WISERTrade Database for the two Ports are at the 6-digit Harmonized System (HS) commodity code level. The data are for Year 2008 and are in dollar values. In the analysis, we only include the data for import and export commodities that exceed $1 million in value in 2008. For both of the two Ports, and on both the import side and export side, the sum of commodities with annual trade value over $1 million accounts for more than 99% of the total value of both import commodities and export commodities..

Waterborne Commerce Statistics Center:

We obtain the domestic import and export data for Port of Port Arthur and Port of Beaumont from the Waterborne Commerce Statistics Center (WCSC) database. The primary mission of WCSC, under the authority of Rivers & Harbors Act of 1922, is to collect, process and distribute data on vessel trips and cargos (WCSC, 2011). The cargo data are presented in tonnages. They are available for all major U.S. ports. WCSC trade data are in a special commodity classification. In the analysis, we have first mapped the commodities to NAICS codes, and then to the sectors used in the I-O analysis. For similar manageability considerations, we only include the data for import and export commodities that exceed 10 thousand short tons in weight in 2008. For both of the two Ports, and on both the import side and export side, the sum of commodities with annual trade volume over 10 thousand short tons account for more than 99% of the total volume of both import commodities and export commodities.

IMPLAN Input-Output Data:

We use the IMPLAN (**IM**pact analysis for **PLAN**ning) data and software (MIG, 2008) to develop the three-county Port MSA Region Input-Output and the U.S. Input-Output models to analyze the economic impacts of port shutdown. IMPLAN data and software consist of three components: 1) a county level, state level, or national level data base, 2) a set of algorithms capable of generating I-O tables for any county, county group or any higher level geographical region, and 3) a computational capability for calculating multipliers and performing impact analyses. The IMPLAN sectoring scheme is currently based on the North American Industrial Classification System (NAICS), and the version of the I-O model we used includes 440 sectors. Both of the Port Region and the U.S. I-O models are for Year 2008. IMPLAN is the most widely used source of input-output data and tables in the U.S. It has been the major economic data input for several previous studies of total economic impacts of port disruptions.

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APPENDIX C. MANUFACTURING INVENTORY PERCENTAGES

Table C-1. Real manufacturing inventory percentages, by stage of fabrication, seasonally adjusted, end of 2009.

	Materials and supplies	Work-in-process	Total
Manufacturing industries	4.4%	3.8%	8.2%
Durable goods industries	5.1%	5.5%	10.6%
Wood product manufacturing	4.2%	1.9%	6.1%
Nonmetallic mineral product manufacturing	5.4%	1.4%	6.8%
Primary metal manufacturing	5.6%	4.1%	9.7%
Fabricated metal product manufacturing	5.5%	4.3%	9.7%
Machinery manufacturing	6.5%	4.6%	11.1%
Computer and electronic product manufacturing	5.3%	6.2%	11.5%
Electrical equipment, appliance, and component manufacturing	5.6%	5.2%	10.8%
Transportation equipment manufacturing	3.8%	8.6%	12.4%
Motor vehicle and parts manufacturing	3.0%	1.7%	4.7%
Other transportation equipment manufacturing	5.0%	19.4%	24.4%
Furniture and related product manufacturing	6.2%	2.3%	8.4%
Miscellaneous durable goods manufacturing	5.4%	3.2%	8.6%
Nondurable goods industries	3.7%	2.1%	5.9%
Food manufacturing	2.4%	1.1%	3.6%
Beverage and tobacco product manufacturing	5.7%	2.7%	8.4%
Textile mills	6.8%	3.7%	10.5%
Textile product mills	5.3%	3.1%	8.4%
Apparel manufacturing	10.2%	5.9%	16.1%
Leather and allied product manufacturing	10.0%	4.3%	14.3%
Paper manufacturing	6.1%	1.3%	7.4%
Printing and related support activities	2.6%	1.3%	4.0%
Petroleum and coal product manufacturing	2.8%	2.7%	5.6%
Chemical manufacturing	4.0%	2.8%	6.8%
Plastics and rubber product manufacturing	5.7%	1.4%	7.2%

Note: Inventory percentages in this table are computed by dividing the real inventories by the end of year 2009 by the total annual sales of 2009.
Source: BEA, 2010.

Table C-2. Resilience factors.

REMI Sectors	Description	LA CGE Sectors	Production Rescheduling[a]	Conservation	Excess Capacity[b]
1	Forestry & logging; Fishing, hunting, & trapping	1	75%	2%	11%
2	Agriculture & forestry support activities; Other	1	75%	2%	11%
3	Oil & gas extraction	2	99%	2%	19%
4	Mining (except oil & gas)	2	99%	2%	19%
5	Support activities for mining	2	99%	2%	19%
6	Utilities	13-16, 30	75%	2%	19%
7	Construction	3	95%	2%	11%
8	Wood product mfg.	9	99%	2%	31%
9	Nonmetallic mineral product mfg.	9	99%	2%	31%
10	Primary metal mfg.	7	99%	2%	21%
11	Fabricated metal product mfg.	9	99%	2%	31%
12	Machinery mfg.	9	99%	2%	31%
13	Computer & electronic product mfg.	8,9	99%	2%	31%
14	Electrical equip. & appliance mfg.	9	99%	2%	31%
15	Motor vehicle mfg.	9	99%	2%	31%
16	Transportation equip. mfg. Excl. motor vehicles	9	99%	2%	31%
17	Furniture & related product mfg.	9	99%	2%	31%
18	Miscellaneous mfg.	9	99%	2%	31%
19	Food mfg.	4	95%	2%	27%
20	Beverage & tobacco product mfg.	4,6	95%	2%	28%
21	Textile mills	6	95%	2%	29%
22	Textile product mills	6	95%	2%	29%
23	Apparel mfg.	6	95%	2%	29%
24	Leather & allied product mfg.	6	95%	2%	29%
25	Paper mfg.	6	95%	2%	29%
26	Printing & related support activities	6	95%	2%	29%
27	Petroleum & coal products mfg.	5	99%	2%	24%
28	Chemical mfg.	6	95%	2%	29%
29	Plastics & rubber products mfg.	6	95%	2%	29%
30	Wholesale trade	17	99%	2%	21%
31	Retail trade	18	80%	2%	21%
32	Air transportation	11	30%	2%	21%
33	Rail transportation	11	30%	2%	21%
34	Water transportation	11	30%	2%	21%
35	Truck transportation; Couriers & messengers	11	30%	2%	21%
36	Transit & ground passenger transportation	10,31	30%	2%	21%

Table C-2. Resilience factors (Continued).

REMI Sectors	Description	LA CGE Sectors	Production Rescheduling[a]	Conservation	Excess Capacity[b]
37	Pipeline transportation	11	30%	2%	21%
38	Scenic & sightseeing transportation; support activities	11	30%	2%	21%
39	Warehousing & storage	11	30%	2%	21%
40	Publishing industries, except Internet	6	95%	2%	29%
41	Motion picture & sound recording industries	27	30%	2%	21%
42	Internet services & data processing; Other inf. services	26	40%	2%	21%
43	Broadcasting, except Internet; Telecommunications	12	40%	2%	21%
44	Monetary authorities	20	90%	2%	21%
45	Securities, commodity contracts, investments	21	90%	2%	21%
46	Insurance carriers & related activities	22	90%	2%	21%
47	Real estate	19	90%	2%	21%
48	Rental & leasing services; Lessors of nonfinancial intangible assets	25	70%	2%	21%
49	Professional & technical services	25	70%	2%	21%
50	Mgt. of companies & enterprises	25	70%	2%	21%
51	Administrative & support services	25	70%	2%	21%
52	Waste mgt. & remediation services	16	90%	2%	21%
53	Educational services	28	99%	2%	21%
54	Ambulatory health care services	29	50%	2%	21%
55	Hospitals	29	50%	2%	21%
56	Nursing & residential care facilities	29	50%	2%	21%
57	Social assistance	29	50%	2%	21%
58	Performing arts & spectator sports	27	30%	2%	21%
59	Museums, historical sites, zoos, & parks	27	30%	2%	21%
60	Amusement, gambling, & recreation	27	30%	2%	21%
61	Accommodation	23	60%	2%	21%
62	Food services & drinking places	23	60%	2%	21%
63	Repair & maintenance	25	70%	2%	21%
64	Personal & laundry services	24	60%	2%	21%
65	Membership associations & organizations	25	70%	2%	21%
66	Private households	24	60%	2%	21%
67	State & local government	32	80%	2%	21%
68	Federal, civilian	32	80%	2%	21%
69	Military	32	80%	2%	21%
70	Farm (agricultural products)	1	75%	2%	11%

[a] Data source for production rescheduling: FEMA (1997) and Rose and Lim (2002). The original sources warn against using the factors for periods longer than 3 months; see Appendix Table C below.

[b] Data source for excess capacity: USDOC et al. (2006), FR (2006), and SC (2006).

Table C-3. Recapture factors for extended periods.

Sector		3 Months or Less (%)	3-6 Months (%)	6-9 Months (%)	9-12 Months (%)	12-24 Months (%)	Longer than 24 Months
1	Agriculture	0.75	0.56	0.42	0.32	0.24	0.00
2	Construction	0.95	0.71	0.53	0.40	0.30	0.00
3	Food, Drugs & Chemicals	0.98	0.74	0.55	0.41	0.31	0.00
4	Mining & Metals/Minerals Processing & Mfg.	0.98	0.74	0.55	0.41	0.31	0.00
5	High Technology	0.98	0.74	0.55	0.41	0.31	0.00
6	Other Heavy Industry	0.98	0.74	0.55	0.41	0.31	0.00
7	Other Light Industry	0.98	0.74	0.55	0.41	0.31	0.00
8	Air Transportation	0.30	0.23	0.17	0.13	0.09	0.00
9	Rail Transportation	0.30	0.23	0.17	0.13	0.09	0.00
10	Water Transportation	0.30	0.23	0.17	0.13	0.09	0.00
11	Highway & Light Rail Transportation	0.30	0.23	0.17	0.13	0.09	0.00
12	Electric Utilities	0.75	0.56	0.42	0.32	0.24	0.00
13	Gas Utilities	0.75	0.56	0.42	0.32	0.24	0.00
14	Water Utilities	0.90	0.68	0.51	0.38	0.28	0.00
15	Wholesale Trade	0.87	0.65	0.49	0.37	0.28	0.00
16	Retail Trade	0.87	0.65	0.49	0.37	0.28	0.00
17	Banks & Financial Institutions	0.90	0.68	0.51	0.38	0.28	0.00
18	Professional & Technical Services	0.90	0.68	0.51	0.38	0.28	0.00
19	Education Services	0.60	0.45	0.34	0.25	0.19	0.00
20	Health Services	0.60	0.45	0.34	0.25	0.19	0.00
21	Entertainment & Recreation	0.60	0.45	0.34	0.25	0.19	0.00
22	Hotels	0.60	0.45	0.34	0.25	0.19	0.00
23	Other Services	0.51	0.38	0.29	0.22	0.16	0.00
24	Gov't & Non-NAICS	0.80	0.60	0.45	0.34	0.25	0.00
25	Real Estate	0.00	0.00	0.00	0.00	0.00	0.00
26	Owner-occupied dwellings	0.00	0.00	0.00	0.00	0.00	0.00

Sources: For column 1-- Table 15.14 in HAZUS-MH MR4 Earthquake Model Technical Manual (FEMA, 2009). For other columns -- Rose et al. (2010).

APPENDIX D. IMPLAN SECTORS AND PORT I-O MODEL SECTORS

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors.

IMPLAN Sector	*I-O Model Sector*
1. Oilseed farming	1. Agriculture, forestry & fishing
2. Grain farming	
3. Vegetable & melon farming	
4. Fruit farming	
5. Tree nut farming	
6. Greenhouse, nursery, & floriculture production	
7. Tobacco farming	
8. Cotton farming	
9. Sugarcane & sugar beet farming	
10. All other crop farming	
11. Cattle ranching & farming	
12. Dairy cattle & milk production	
13. Poultry & egg production	
14. Animal production, except cattle & poultry & eggs	
15. Forest nurseries, forest products, & timber tracts	
16. Logging	
17. Fishing	
18. Hunting & trapping	
19. Support activities for agriculture & forestry	
20. Oil & gas extraction	5. Oil & gas extraction & all other mining
21. Coal mining	2. Coal mining
22. Iron ore mining	5. Oil & gas extraction & all other mining
23. Copper, nickel, lead, & zinc mining	
24. Gold, silver, & other metal ore mining	
25. Stone mining & quarrying	
26. S&, gravel, clay, & ceramic & refractory minerals mining & quarrying	3. S&, gravel, clay & ceramic & refractory minerals
27. Other nonmetallic mineral mining & quarrying	5. Oil & gas extraction & all other mining
28. Drilling oil & gas wells	
29. Support activities for oil & gas operations	4. Support activities for oil & gas operations
30. Support activities for other mining	5. Oil & gas extraction & all other mining
31. Electric power generation, transmission, & distribution	6. Electric power generation, transmission, & distribution
32. Natural gas distribution	7. Natural gas distribution
33. Water, sewage & other systems	8. Water, sewage & other systems
34. Construction of new nonresidential commercial & health care structures	9. Construction
35. Construction of new nonresidential mfg structures	
36. Construction of other new nonresidential structures	
37. Construction of new residential permanent site single- & multi-family structures	
38. Construction of other new residential structures	
39. Maintenance & repair construction of nonresidential maintenance & repair	
40. Maintenance & repair construction of residential structures	
41. Dog & cat food mfg	10. Food, beverage, & tobacco mfg
42. Other animal food mfg	
43. Flour milling & malt mfg	
44. Wet corn milling	
45. Soybean & other oilseed processing	
46. Fats & oils refining & blending	
47. Breakfast cereal mfg	
48. Sugar cane mills & refining	
49. Beet sugar mfg	
50. Chocolate & confectionery mfg from cacao beans	
51. Confectionery mfg from purchased chocolate	
52. Nonchocolate confectionery mfg	
53. Frozen food mfg	
54. Fruit & vegetable canning, pickling, & drying	
55. Fluid milk & butter mfg	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
56. Cheese mfg	10. Food, beverage, & tobacco mfg
57. Dry, condensed, & evaporated dairy product mfg	
58. Ice cream & frozen dessert mfg	
59. Animal (except poultry) slaughtering, rendering, & processing	
60. Poultry processing	
61. Seafood product preparation & packaging	
62. Bread & bakery product mfg	
63. Cookie, cracker, & pasta mfg	
64. Tortilla mfg	
65. Snack food mfg	
66. Coffee & tea mfg	
67. Flavoring syrup & concentrate mfg	
68. Seasoning & dressing mfg	
69. All other food mfg	
70. Soft drink & ice mfg	
71. Breweries	
72. Wineries	
73. Distilleries	
74. Tobacco product mfg	
75. Fiber, yarn, & thread mills	11. Textile & mills, apparel & leather product mfg
76. Broadwoven fabric mills	
77. Narrow fabric mills & schiffli machine embroidery	
78. Nonwoven fabric mills	
79. Knit fabric mills	
80. Textile & fabric finishing mills	
81. Fabric coating mills	
82. Carpet & rug mills	
83. Curtain & linen mills	
84. Textile bag & canvas mills	
85. All other textile product mills	
86. Apparel knitting mills	
87. Cut & sew apparel contractors	
88. Men's & boys' cut & sew apparel mfg	
89. Women's & girls' cut & sew apparel mfg	
90. Other cut & sew apparel mfg	
91. Apparel accessories & other apparel mfg	
92. Leather & hide tanning & finishing	
93. Footwear mfg	
94. Other leather & allied product mfg	
95. Sawmills & wood preservation	12. Wood product mfg
96. Veneer & plywood mfg	
97. Engineered wood member & truss mfg	
98. Reconstituted wood product mfg	
99. Wood windows & doors & millwork	
100. Wood container & pallet mfg	
101. Manufactured home (mobile home) mfg	
102. Prefabricated wood building mfg	
103. All other miscellaneous wood product mfg	13. All other miscellaneous wood product mfg
104. Pulp mills	14. Pulp mills
105. Paper mills	16. Other paper & printing
106. Paperboard Mills	
107. Paperboard container mfg	15. Paperboard container & coated paper mfg
108. Coated & laminated paper, packaging paper & plastics film mfg	
109. All other paper bag & coated & treated paper mfg	16. Other paper & printing
110. Stationery product mfg	
111. Sanitary paper product mfg	
112. All other converted paper product mfg	
113. Printing	
114. Support activities for printing	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
115. Petroleum refineries	17. Petroleum refineries
116. Asphalt paving mixture & block mfg	19. All other petroleum & coal products mfg
117. Asphalt shingle & coating materials mfg	
118. Petroleum lubricating oil & grease mfg	18. Petroleum lubricating oil & grease mfg
119. All other petroleum & coal products mfg	19. All other petroleum & coal products mfg
120. Petrochemical mfg	20. Petrochemical mfg
121. Industrial gas mfg	25. Other chemical mfg
122. Synthetic dye & pigment mfg	
123. Alkalies & chlorine mfg	21. Alkalies & chlorine mfg
124. Carbon black mfg	25. Other chemical mfg
125. All other basic inorganic chemical mfg	
126. Other basic organic chemical mfg	22. Other basic organic chemical mfg
127. Plastics material & resin mfg	25. Other chemical mfg
128. Synthetic rubber mfg	23. Synthetic rubber mfg
129. Artificial & synthetic fibers & filaments mfg	25. Other chemical mfg
130. Fertilizer mfg	24. Fertilizer mfg
131. Pesticide & other agricultural chemical mfg	25. Other chemical mfg
132. Medicinal & botanical mfg	
133. Pharmaceutical preparation mfg	
134. In-vitro diagnostic substance mfg	
135. Biological product (except diagnostic) mfg	
136. Paint & coating mfg	
137. Adhesive mfg	
138. Soap & cleaning compound mfg	
139. Toilet preparation mfg	
140. Printing ink mfg	
141. All other chemical product & preparation mfg	
142. Plastics packaging materials & unlaminated film & sheet mfg	26. Plastics & rubber products mfg
143. Unlaminated plastics profile shape mfg	
144. Plastics pipe & pipe fitting mfg	
145. Laminated plastics plate, sheet (except packaging), & shape mfg	
146. Polystyrene foam product mfg	
147. Urethane & other foam product (except polystyrene) mfg	
148. Plastics bottle mfg	
149. Other plastics product mfg	
150. Tire mfg	
151. Rubber & plastics hoses & belting mfg	
152. Other rubber product mfg	
153. Pottery, ceramics, & plumbing fixture mfg	29. Other nonmetallic mineral product mfg
154. Brick, tile, & other structural clay product mfg	
155. Clay & nonclay refractory mfg	
156. Flat glass mfg	
157. Other pressed & blown glass & glassware mfg	
158. Glass container mfg	
159. Glass product mfg made of purchased glass	
160. Cement mfg	
161. Ready-mix concrete mfg	
162. Concrete pipe, brick, & block mfg	
163. Other concrete product mfg	
164. Lime & gypsum product mfg	27. Lime & gypsum product mfg
165. Abrasive product mfg	29. Other nonmetallic mineral product mfg
166. Cut stone & stone product mfg	
167. Ground or treated mineral & earth mfg	28. Ground or treated mineral & earth mfg
168. Mineral wool mfg	29. Other nonmetallic mineral product mfg
169. Miscellaneous nonmetallic mineral products	
170. Iron & steel mills & ferroalloy mfg	30. Iron & steel mills & ferroalloy mfg

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
171. Steel product mfg from purchased steel	31. Other primary metal & fabricated metal mfg
172. Alumina refining & primary aluminum production	
173. Secondary smelting & alloying of aluminum	
174. Aluminum product mfg from purchased aluminum	
175. Primary smelting & refining of copper	
176. Primary smelting & refining of nonferrous metal (except copper & aluminum)	
177. Copper rolling, drawing, extruding & alloying	
178. Nonferrous metal (except copper & aluminum) rolling, drawing, extruding &	
179. Ferrous metal foundries	
180. Nonferrous metal foundries	
181. All other forging, stamping, & sintering	
182. Custom roll forming	
183. Crown & closure mfg & metal stamping	
184. Cutlery, utensil, pot, & pan mfg	
185. H&tool mfg	
186. Plate work & fabricated structural product mfg	
187. Ornamental & architectural metal products mfg	
188. Power boiler & heat exchanger mfg	
189. Metal tank (heavy gauge) mfg	
190. Metal can, box, & other metal container (light gauge) mfg	
191. Ammunition mfg	
192. Arms, ordnance, & accessories mfg	
193. Hardware mfg	
194. Spring & wire product mfg	
195. Machine shops	
196. Turned product & screw, nut, & bolt mfg	
197. Coating, engraving, heat treating & allied activities	
198. Valve & fittings other than plumbing	
199. Plumbing fixture fitting & trim mfg	
200. Ball & roller bearing mfg	
201. Fabricated pipe & pipe fitting mfg	
202. Other fabricated metal mfg	
203. Farm machinery & equipment mfg	33. Other machinery & equipment mfg
204. Lawn & garden equipment mfg	
205. Construction machinery mfg	
206. Mining & oil & gas field machinery mfg	
207. Other industrial machinery mfg	
208. Plastics & rubber industry machinery mfg	
209. Semiconductor machinery mfg	
210. Vending, commercial, industrial, & office machinery mfg	
211. Optical instrument & lens mfg	
212. Photographic & photocopying equipment mfg	
213. Other commercial & service industry machinery mfg	
214. Air purification & ventilation equipment mfg	
215. Heating equipment (except warm air furnaces) mfg	
216. Air conditioning, refrigeration, & warm air heating equipment mfg	
217. Industrial mold mfg	
218. Metal cutting & forming machine tool mfg	
219. Special tool, die, jig, & fixture mfg	
220. Cutting tool & machine tool accessory mfg	
221. Rolling mill & other metalworking machinery mfg	
222. Turbine & turbine generator set units mfg	
223. Speed changer, industrial high-speed drive, & gear mfg	
224. Mechanical power transmission equipment mfg	
225. Other engine equipment mfg	
226. Pump & pumping equipment mfg	
227. Air & gas compressor mfg	
228. Material h&ling equipment mfg	
229. Power-driven h&tool mfg	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
230. Other general purpose machinery mfg	33. Other machinery & equipment mfg
231. Packaging machinery mfg	
232. Industrial process furnace & oven mfg	
233. Fluid power process machinery	
234. Electronic computer mfg	
235. Computer storage device mfg	
236. Computer terminals & other computer peripheral equipment mfg	
237. Telephone apparatus mfg	
238. Broadcast & wireless communications equipment	
239. Other communications equipment mfg	
240. Audio & video equipment mfg	
241. Electron tube mfg	
242. Bare printed circuit board mfg	
243. Semiconductor & related device mfg	
244. Electronic capacitor, resistor, coil, transformer, & other inductor mfg	
245. Electronic connector mfg	
246. Printed circuit assembly (electronic assembly) mfg	
247. Other electronic component mfg	
248. Electromedical & electrotherapeutic apparatus mfg	
249. Search, detection, & navigation instruments mfg	
250. Automatic environmental control mfg	
251. Industrial process variable instruments mfg	
252. Totalizing fluid meters & counting devices mfg	
253. Electricity & signal testing instruments mfg	
254. Analytical laboratory instrument mfg	
255. Irradiation apparatus mfg	
256. Watch, clock, & other measuring & controlling device mfg	
257. Software, audio, & video media reproducing	
258. Magnetic & optical recording media mfg	
259. Electric lamp bulb & part mfg	
260. Lighting fixture mfg	
261. Small electrical appliance mfg	
262. Household cooking appliance mfg	
263. Household refrigerator & home freezer mfg	
264. Household laundry equipment mfg	
265. Other major household appliance mfg	
266. Power, distribution, & specialty transformer mfg	
267. Motor & generator mfg	
268. Switchgear & switchboard apparatus mfg	
269. Relay & industrial control mfg	
270. Storage battery mfg	
271. Primary battery mfg	
272. Communication & energy wire & cable mfg	
273. Wiring device mfg	
274. Carbon & graphite product mfg	
275. All other miscellaneous electrical equipment & component mfg	
276. Automobile mfg	32. Motor vehile mfg
277. Light truck & utility vehicle mfg	
278. Heavy duty truck mfg	
279. Motor vehicle body mfg	33. Other machinery & equipment mfg
280. Truck trailer mfg	32. Motor vehile mfg
281. Motor home mfg	
282. Travel trailer & camper mfg	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
283. Motor vehicle parts mfg	33. Other machinery & equipment mfg
284. Aircraft mfg	
285. Aircraft engine & engine parts mfg	
286. Other aircraft parts & auxiliary equipment mfg	
287. Guided missile & space vehicle mfg	
288. Propulsion units & parts for space vehicles & guided missiles	
289. Railroad rolling stock mfg	
290. Ship building & repairing	
291. Boat building	
292. Motorcycle, bicycle, & parts mfg	
293. Military armored vehicle, tank, & tank component mfg	
294. All other transportation equipment mfg	
295. Wood kitchen cabinet & countertop mfg	34. Miscellaneous mfg
296. Upholstered household furniture mfg	
297. Nonupholstered wood household furniture mfg	
298. Metal & other household furniture (except wood) mfg1	
299. Institutional furniture mfg	
300. Wood television, radio, & sewing machine cabinet mfg1	
301. Office furniture & custom architectural woodwork & millwork mfg1	
302. Showcase, partition, shelving, & locker mfg	
303. Mattress mfg	
304. Blind & shade mfg	
305. Surgical & medical instrument mfg	
306. Surgical appliance & supplies mfg	
307. Dental equipment & supplies mfg	
308. Ophthalmic goods mfg	
309. Dental laboratories	
310. Jewelry & silverware mfg	
311. Sporting & athletic goods mfg	
312. Doll, toy, & game mfg	
313. Office supplies (except paper) mfg	
314. Sign mfg	
315. Gasket, packing, & sealing device mfg	
316. Musical instrument mfg	
317. All other miscellaneous mfg	
318. Broom, brush, & mop mfg	
319. Wholesale trade	35. Wholesale trade
320. Retail - Motor vehicle & parts	36. Retail trade
321. Retail - Furniture & home furnishings	
322. Retail - Electronics & appliances	
323. Retail - Building material & garden supply	
324. Retail - Food & beverage	
325. Retail - Health & personal care	
326. Retail - Gasoline stations	
327. Retail - Clothing & clothing accessories	
328. Retail - Sporting goods, hobby, book & music	
329. Retail - General merch&ise	
330. Retail - Miscellaneous	
331. Retail - Nonstore	
332. Air transportation	37. Air transportation
333. Rail transportation	38. Rail transportation
334. Water transportation	39. Water transportation
335. Truck transportation	40. Truck transportation
336. Transit & ground passenger transportation	41. Other transportation
337. Pipeline transportation	42. Pipeline transportation
338. Scenic & sightseeing transportation & support activities for transportation	41. Other transportation
339. Couriers & messengers	
340. Warehousing & storage	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
341. Newspaper publishers	43. Information & Communication
342. Periodical publishers	
343. Book publishers	
344. Directory, mailing list, & other publishers	
345. Software publishers	
346. Motion picture & video industries	
347. Sound recording industries	
348. Radio & television broadcasting	
349. Cable & other subscription programming	
350. Internet publishing & broadcasting	
351. Telecommunications	
352. Data processing, hosting, & related services	
353. Other information services	
354. Monetary authorities & depository credit intermediation	44. Finance, insureance, real estate, & leasing
355. Nondepository credit intermediation & related activities	
356. Securities, commodity contracts, investments, & related activities	
357. Insurance carriers	
358. Insurance agencies, brokerages, & related activities	
359. Funds, trusts, & other financial vehicles	
360. Real estate	
361. Imputed rental value for owner-occupied dwellings	45. Imputed rental for owner-occupied dwellings
362. Automotive equipment rental & leasing	44. Finance, insureance, real estate, & leasing
363. General & consumer goods rental except video tapes & discs	
364. Video tape & disc rental	
365. Commercial & industrial machinery & equipment rental & leasing	
366. Lessors of nonfinancial intangible assets	
367. Legal services	47. Other business services
368. Accounting, tax preparation, bookkeeping, & payroll services	
369. Architectural, engineering, & related services	
370. Specialized design services	
371. Custom computer programming services	
372. Computer systems design services	
373. Other computer related services, including facilities management	
374. Management, scientific, & technical consulting services	
375. Environmental & other technical consulting services	
376. Scientific research & development services	
377. Advertising & related services	
378. Photographic services	
379. Veterinary services	
380. All other miscellaneous professional, scientific, & technical services	
381. Management of companies & enterprises	
382. Employment services	
383. Travel arrangement & reservation services	
384. Office administrative services	
385. Facilities support services	
386. Business support services	
387. Investigation & security services	
388. Services to buildings & dwellings	
389. Other support services	

Table D-1. Table of IMPLAN Sectors and Port I-O model sectors (Continued).

IMPLAN Sector	*I-O Model Sector*
390. Waste management & remediation services	46. Waste management & remediation services
391. Elementary & secondary schools	48. Health, education & social services
392. Junior colleges, colleges, universities, & professional schools	
393. Other educational services	
394. Offices of physicians, dentists, & other health practitioners	
395. Home health care services	
396. Medical & diagnostic labs & outpatient & other ambulatory care services	
397. Hospitals	
398. Nursing & residential care facilities	
399. Child day care services	
400. Individual & family services	
401. Community food, housing, & other relief services, including rehabilitation	
402. Performing arts companies	49. Accomodations, food services, & amusements
403. Spectator sports	
404. Promoters of performing arts & sports & agents for public figures	
405. Independent artists, writers, & performers	
406. Museums, historical sites, zoos, & parks	
407. Fitness & recreational sports centers	
408. Bowling centers	
409. Amusement parks, arcades, & gambling industries	
410. Other amusement & recreation industries	
411. Hotels & motels, including casino hotels	
412. Other accommodations	
413. Food services & drinking places	
414. Automotive repair & maintenance, except car washes	47. Other business services
415. Car washes	
416. Electronic & precision equipment repair & maintenance	
417. Commercial & industrial machinery & equipment repair & maintenance	
418. Personal & household goods repair & maintenance	50. Personal services
419. Personal care services	
420. Death care services	
421. Dry-cleaning & laundry services	
422. Other personal services	
423. Religious organizations	47. Health, education & social services
424. Grantmaking, giving, & social advocacy organizations	
425. Civic, social, professional, & similar organizations	
426. Private households	50. Personal services
427. Postal service	51. Government & Non-NAICS
428. Federal electric utilities	
429. Other Federal Government enterprises	
430. State & local government passenger transit	
431. State & local government electric utilities	
432. Other state & local government enterprises	
433. *Not an industry (Used & secondh& goods)	
434. *Not an industry (Scrap)	
435. *Not an industry (Rest of the world adjustment)	
436. *Not an industry (Noncomparable imports)	
437. Employment & payroll for SL Government Non-Education	
438. Employment & payroll for SL Government Education	
439. Employment & payroll for Federal Non-Military	
440. Employment & payroll for Federal Military	

APPENDIX E. DOMESTIC/FOREIGN IMPORTS/EXPORTS TO PORTS OF PORT ARTHUR AND BEAUMONT

Table E-1. Foreign imports to port of Port Arthur, 2008.

Rank	HS Code	Commodity Description	I-O Model Sector	Import Value ($)
1	270900	Crude Oil From Petroleum and Bituminous Minerals	5 Oil and gas extraction and all other mining	14,092,575,171
2	271019	Oil (Not Crude) From Petrol & Bitum Mineral Etc.	17 Petroleum refineries	319,483,206
3	470329	Chem Woodpulp, Soda Etc, N Dis S Bl & Bl Nonconif	14 Pulp mills	113,300,973
4	271011	Light Oils& Prep (Not Crude) From Petrol & Bitum	17 Petroleum refineries	59,604,619
5	271311	Petroleum Coke, Not Calcined	17 Petroleum refineries	59,040,934
6	280700	Sulfuric Acid; Oleum	25. Other chemical mfg	58,855,775
7	841950	Heat Exchange Units, Industrial Type	31 Other primary metal and fabricated metal product mfg	55,709,212
8	841940	Distilling or Rectifying Plant	33 Other machinery and equipment mfg	27,460,320
9	290220	Benzene	17 Petroleum refineries	24,008,709
10	730900	Tanks Etc, Over 300 Liter Capacity, Iron or Steel	31 Other primary metal and fabricated metal product mfg	21,171,731
11	841990	Parts for Machinery Plant or Lab Equipment Etc	33 Other machinery and equipment mfg	14,524,871
12	880230	Airplane & A/C Unladen Wght > 2000, Nov 15000 Kg	33 Other machinery and equipment mfg	13,415,857
13	281410	Anhydrous Ammonia	25 Other chemical mfg	13,098,363
14	721391	Bars, Rodshot-Roll, Irnnoal St Coil Circ,	31 Other primary metal and fabricated metal product mfg	6,601,434
15	271114	Ethylene, Propylene, Butylene, Butadiene Liquefied	17 Petroleum refineries	6,374,703
16	902810	Gas Meters	33 Other machinery and equipment mfg	6,097,327
17	382490	Products and Residuals of Chemical Industry, Nesoi	25 Other chemical mfg	5,480,165
18	251710	Pebbles, Gravel Etc. for Concrete Aggregates Etc.	3 Sand, gravel, clay and ceramic and refractory minerals	5,292,065
19	840410	Auxiliary Plant for Steam, Water and Central Boilr	31 Other primary metal and fabricated metal product mfg	4,575,724
20	480100	Newsprint, In Rolls or Sheets	16 Other paper and printing	2,497,441
21	840290	Super-Heated Water Boilers & Steam Genrtn Boil Pts	31 Other primary metal and fabricated metal product mfg	2,392,686
22	850164	Ac Generators of An Output Exceeding 750 Kva	33 Other machinery and equipment mfg	1,819,000
23	730890	Structures and Parts Nesoi of Iron or Steel	31 Other primary metal and fabricated metal product mfg	1,638,997
24	842890	Lifting, Handling, Loading & Unloading Machy Nesoi	33 Other machinery and equipment mfg	1,367,574
25	292211	Monoethanolamine and Its Salts	22 Other basic organic chemical mfg	1,298,395

Note: This table includes import commodities more than $1,000,000. The sum of these commodities account for more than 99% of the total value of foreign imports shipped to Port of Port Arthur.

Table E-2. Foreign exports from port of Port Arthur, 2008.

Rank	HS Code	Commodity Description	I-O Model Sector	Export Value ($)
1	271019	Oil (Not Crude) From Petrol & Bitum Mineral Etc.	17 Petroleum refineries	1,411,579,039
2	283620	Disodium Carbonate	21. Alkalies and chlorine mfg	265,598,418
3	271312	Petroleum Coke, Calcined	17 Petroleum refineries	189,459,260
4	271011	Light Oils& Prep (Not Crude) From Petrol & Bitum	17 Petroleum refineries	151,619,128
5	271311	Petroleum Coke, Not Calcined	17 Petroleum refineries	120,222,677
6	290211	Cyclohexane	25. Other chemical mfg	80,953,120
7	100190	Wheat (Other Than Durum Wheat), and Meslin	1. Agriculture, forestry and fishing	80,207,518
8	281520	Potassium Hydroxide (Caustic Potash)	21. Alkalies and chlorine mfg	56,685,563
9	250300	Sulfur of All Kinds, Not Sublimed, Precip, Colloidal	25. Other chemical mfg	21,872,937
10	470329	Chem Woodpulp, Soda Etc, N Dis S Bl & Bl Nonconif	14. Pulp mills	11,857,545
11	480411	Kraftliner, Uncoated Unbleached In Rolls or Sheets	16. Other paper and printing	11,305,562
12	262190	Ash and Slag, Including Seaweed Ash (Kelp), Nesoi	1. Agriculture, forestry and fishing	9,493,099
13	470321	Chemical Woodpulp, Soda Etc. N Dis S Bl & Bl Conif	14. Pulp mills	9,073,216
14	290531	Ethylene Glycol (Ethanediol)	25. Other chemical mfg	6,735,000
15	290124	Buta-1, 3-Diene and Isoprene	17. Petroleum refineries	4,264,920
16	280700	Sulfuric Acid; Oleum	25. Other chemical mfg	2,843,629
17	271114	Ethylene, Propylene, Butylene, Butadiene Liquefied	17. Petroleum refineries	2,654,439
18	480419	Kraftliner, Uncoated, Bleached, In Rolls or Sheets	16. Other paper and printing	2,213,238
19	840999	Spark-Ignition Reciprocating Int Com Pistn Eng Pts	33. Other machinery and equipment mfg	2,142,599
20	841690	Parts of Furnace Burners	33. Other machinery and equipment mfg	1,142,390

Note: This table includes export commodities more than $1,000,000. The sum of these commodities account for more than 99% of the total value of foreign export shipped from Port of Port Arthur.

Table E-3. Foreign import of Port of Beaumont, 2008.

Rank	HS Code	Commodity Description	I-O Model Sector	Import Value ($)
1	270900	Crude Oil From Petroleum and Bituminous Minerals	5 Oil and gas extraction and all other mining	15,482,968,896
2	271011	Light Oils& Prep (Not Crude) From Petrol & Bitum	17 Petroleum refineries	1,074,206,652
3	271019	Oil (Not Crude) From Petrol & Bitum Mineral Etc.	17 Petroleum refineries	735,084,985
4	850231	Generating Sets, Electric, Wind-Powered	33. Other machinery and equipment mfg	511,909,519
5	281410	Anhydrous Ammonia	25 Other chemical mfg	191,832,623
6	730519	Pipe, Oil Line Etc Ov16in Ir or Steel, Close Nesoi	30. Iron and steel mills and ferroalloy mfg	92,016,793
7	290511	Methanol (Methyl Alcohol)	22. Other basic organic chemical mfg	91,060,601
8	841290	Engine and Motor Parts, Nesoi	33. Other machinery and equipment mfg	48,381,810
9	271114	Ethylene, Propylene, Butylene, Butadiene Liquefied	17 Petroleum refineries	40,528,395
10	280700	Sulfuric Acid; Oleum	25. Other chemical mfg	40,116,144
11	840290	Super-Heated Water Boilers & Steam Genrtn Boil Pts	31 Other primary metal and fabricated metal product mfg	38,731,370
12	730210	Railway or Tramway Rails of Iron or Steel	30. Iron and steel mills and ferroalloy mfg	31,263,001
13	470329	Chem Woodpulp, Soda Etc, N Dis S Bl & Bl Nonconif	14. Pulp mills	24,416,010
14	290110	Acyclic Hydrocarbons, Saturated	17. Petroleum refineries	21,242,878
15	200911	orange Juice, Frozen, Sweetened or Not	10. Food, beverage, and tobacco mfg	20,025,684
16	270750	Arom Hydc Nesoi 65pct Ao Dstls A 250dc Astm D 86	20. Petrochemical mfg	6,965,000
17	200912	orange Juice, Not Frozen, of A Brix Value Not Ov 20	10. Food, beverage, and tobacco mfg	5,111,872
18	860900	Containers for One or More Modes of Transport	31 Other primary metal and fabricated metal product mfg	4,252,761
19	730890	Structures and Parts Nesoi of Iron or Steel	31 Other primary metal and fabricated metal product mfg	3,309,782
20	440890	Veneer Sheet Etc, Not Ov 6mm, Nonconiferous Nesoi	12. Wood product mfg	3,104,326
21	290211	Cyclohexane	22. Other basic organic chemical mfg	2,585,105
22	251710	Pebbles, Gravel Etc. for Concrete Aggregates Etc.	3 Sand, gravel, clay and ceramic and refractory minerals	2,468,206
23	730820	Towers and Lattice Masts of Iron or Steel	31 Other primary metal and fabricated metal product mfg	2,375,490
24	441192	Fiberboard, of A Density Exceeding 0.8 G/Cm3 Nesoi	12. Wood product mfg	2,164,944
25	721391	Bars, Rodshot-Roll, Irnnoal St Coil Circ,	31 Other primary metal and fabricated metal product mfg	1,226,446

Note: This table includes import commodities more than $1,000,000. The sum of these commodities account for more than 99% of the total value of foreign import shipped to Port of Beaumont.

Table E-4. Foreign exports from Port of Beaumont, 2008.

Rank	HS Code	Commodity Description	I-O Model Sector	Export Value ($)
1	271011	Light Oils& Prep (Not Crude) From Petrol & Bitum	17 Petroleum refineries	995,698,615
2	290919	Acyclic Ethers (Excl Diethyl Ether) Nesoi	22. Other basic organic chemical mfg	537,750,879
3	100190	Wheat (Other Than Durum Wheat), and Meslin	1. Agriculture, forestry and fishing	503,346,282
4	271019	Oil (Not Crude) From Petrol & Bitum Mineral Etc.	17 Petroleum refineries	291,414,614
5	290243	Para-Xylene	22. Other basic organic chemical mfg	196,590,641
6	310490	Mineral or Chemical Fertilizer, Potassic, Nesoi	24. Fertilizer mfg	104,554,063
7	281520	Potassium Hydroxide (Caustic Potash)	21. Alkalies and chlorine mfg	61,321,648
8	120100	Soybeans, Whether or Not Broken	1. Agriculture, forestry and fishing	43,094,018
9	250300	Sulfur of All Kinds, Not Sublimed, Precip, Colloidal	25. Other chemical mfg	24,395,910
10	271311	Petroleum Coke, Not Calcined	17 Petroleum refineries	17,100,490
11	310221	Ammonium Sulfate	24. Fertilizer mfg	14,005,307
12	310420	Potassium Chloride	24. Fertilizer mfg	11,084,806
13	890690	Vessels, (Include Lifeboats, Other Than Row Bt), Nesoi	33. Other machinery and equipment mfg	8,024,000
14	290941	2,2-Oxydiethanol (Diethylene Glycol, Digol)	22. Other basic organic chemical mfg	5,891,575
15	071340	Lentils, Dried Shelled, Including Seed	1. Agriculture, forestry and fishing	4,497,615
16	310430	Potassium Sulfate	24. Fertilizer mfg	4,118,891
17	290211	Cyclohexane	25. Other chemical mfg	3,679,657
18	290242	Meta-Xylene	22. Other basic organic chemical mfg	3,213,114
19	940600	Prefabricated Buildings	12. Wood product mfg	2,103,800
20	880000	Civilian Aircraft, Engines, and Parts	33. Other machinery and equipment mfg	2,100,000
21	100620	Rice, Husked (Brown)	10. Food, beverage, and tobacco mfg	1,983,788
22	071310	Peas, Dried Shelled, Including Seed	1. Agriculture, forestry and fishing	1,809,067
23	843143	Parts for Boring or Sinking Machinery, Nesoi	33. Other machinery and equipment mfg	1,651,210
24	290531	Ethylene Glycol (Ethanediol)	25. Other chemical mfg	1,554,270
25	850239	Generating Sets, Electric, Nesoi	33. Other machinery and equipment mfg	1,487,516
26	280700	Sulfuric Acid; Oleum	25. Other chemical mfg	1,340,000
27	470329	Chem Woodpulp, Soda Etc, N Dis S Bl & Bl Nonconif	14 Pulp mills	1,310,426
28	850300	Parts of Electric Motors, Generators & Sets	33. Other machinery and equipment mfg	1,140,865

Note: This table includes export commodities more than $1,000,000. The sum of these commodities account for more than 99% of the total value of foreign export shipped from Port of Beaumont.

Table E-5. Domestic imports to port of Port Arthur, 2008.

Rank	Commodity	I-O Model Sector	Import Amount (short tons)	Import Value ($)
1	Distillate Fuel Oil	17 Petroleum refineries	1,628,128	1,070,096,900
2	Waste and Scrap NEC	51 Government and Non-NAICS	726,796	875,152,320
3	Gasoline	17 Petroleum refineries	574,298	357,027,081
4	Residual Fuel Oil	17 Petroleum refineries	440,795	203,146,393
5	Petroleum Coke	17 Petroleum refineries	402,900	70,546,805
6	Benzene & Toluene	20 Petrochemical mfg	225,151	196,748,997
7	Naphtha & Solvents	17 Petroleum refineries	192,012	114,666,701
8	Sand & Gravel	3 Sand, gravel, clay and ceramic and refractory minerals	155,579	1,092,561
9	Lube Oil & Greases	18 Petroleum lubricating oil and grease mfg	149,134	89,060,599
10	Acyclic Hydrocarbons	20 Petrochemical mfg	93,241	135,959,467
11	Hydrocarbon & Petrol Gases, Liquefied and Gaseous	17 Petroleum refineries	92,088	54,490,174
12	Petro. Products NEC	17 Petroleum refineries	55,562	32,133,469
13	Coal Coke	19 All other petroleum and coal products mfg	35,815	16,671,881
14	Other Hydrocarbons	20 Petrochemical mfg	17,035	10,079,925
15	Metallic Salts	25 Other chemical mfg	16,333	260,219,129

Note: This table includes import commodities more than 10,000 short tons. The sum of these commodities account for more than 99% of the total quantity of domestic import shipped to Port of Port Arthur.

Table E-6. Domestic exports from port of Port Arthur, 2008.

Rank	Commodity	I-O Model Sector	Export Amount (short tons)	Export Value ($)
1	Distillate Fuel Oil	17 Petroleum refineries	1,422,395	934,877,651
2	Residual Fuel Oil	17 Petroleum refineries	1,169,283	538,880,031
3	Lube Oil & Greases	18. Petroleum lubricating oil and grease mfg	710,306	473,757,454
4	Gasoline	17 Petroleum refineries	685,392	426,091,515
5	Naphtha & Solvents	17 Petroleum refineries	377,844	252,013,092
6	Petroleum Coke	17 Petroleum refineries	372,202	45,579,460
7	Other Hydrocarbons	20. Petrochemical mfg	173,980	89,857,428
8	Asphalt, Tar & Pitch	17 Petroleum refineries	40,923	24,828,218
9	Crude Petroleum	5 Oil and gas extraction and all other mining	31,199	15,581,359
10	Petro. Products NEC	17 Petroleum refineries	27,833	16,608,542
11	Benzene & Toluene	20. Petrochemical mfg	25,916	10,814,876
12	Sodium Hydroxide	21. Alkalies and chlorine mfg	25,842	15,572,535

Note: This table includes export commodities more than 10,000 short tons. The sum of these commodities account for more than 99% of the total quantity of domestic export shipped from Port of Port Arthur.

Table E-7. Domestic import of Port of Beaumont, 2008.

Rank	Commodity	I-O Model Sector	Import Amount (short tons)	Import Value ($)
1	Distillate Fuel Oil	17 Petroleum refineries	1,874,517	1,232,037,549
2	Naphtha & Solvents	17 Petroleum refineries	1,742,117	1,040,366,273
3	Residual Fuel Oil	17 Petroleum refineries	537,187	247,569,962
4	Petro. Products NEC	17 Petroleum refineries	528,677	305,752,602
5	Lube Oil & Greases	18 Petroleum lubricating oil and grease mfg	425,773	254,265,281
6	Crude Petroleum	5 Oil and gas extraction and all other mining	392,616	196,079,710
7	Benzene & Toluene	20 Petrochemical mfg	389,882	340,699,763
8	Gasoline	17 Petroleum refineries	321,699	199,992,434
9	Acyclic Hydrocarbons	20 Petrochemical mfg	211,476	308,363,962
10	Hydrocarbon & Petrol Gases, Liquefied and Gaseous	17 Petroleum refineries	143,573	84,954,801
11	Limestone	5 Oil and gas extraction and all other mining	97,105	681,924
12	Sulphur (Liquid)	25. Other chemical mfg	94,669	95,783,118
13	Other Hydrocarbons	20 Petrochemical mfg	82,639	48,899,026
14	Ammonia	25. Other chemical mfg	73,500	33,881,450
15	Organic Comp. NEC	22. Other basic organic chemical mfg	71,402	385,424,408
16	Iron & Steel Scrap	51 Government and Non-NAICS	63,670	22,210,401
17	Sand & Gravel	3 Sand, gravel, clay and ceramic and refractory minerals	63,191	443,762
18	Chemical Additives	25. Other chemical mfg	62,580	108,106,595
19	Pig Iron	31. Other primary metal and fabricated metal mfg	54,379	27,396,011
20	Sodium Hydroxide	21. Alkalies and chlorine mfg	47,648	21,129,323
21	Asphalt, Tar & Pitch	17 Petroleum refineries	39,173	21,392,473
22	Alcohols	10. Food, beverage, and tobacco mfg	16,358	23,670,277
23	Sulphuric Acid	25. Other chemical mfg	16,127	3,366,378
24	Iron Ore	5. Oil and gas extraction and all other mining	11,047	999,538

Note: This table includes import commodities more than 10,000 short tons. The sum of these commodities account for more than 99% of the total quantity of domestic import shipped to Port of Beaumont.

Table E-8. Domestic exports from Port of Beaumont, 2008.

Rank	Commodity	I-O Model Sector	Export Amount (short tons)	Export Value ($)
1	Crude Petroleum	5 Oil and gas extraction and all other mining	3,211,920	1,604,092,399
2	Gasoline	17 Petroleum refineries	2,235,849	1,389,972,874
3	Residual Fuel Oil	17 Petroleum refineries	1,911,046	880,731,635
4	Distillate Fuel Oil	17 Petroleum refineries	1,518,707	998,179,291
5	Asphalt, Tar & Pitch	17 Petroleum refineries	1,043,392	633,031,900
6	Sulphur (Liquid)	25. Other chemical mfg	846,413	82,797,469
7	Naphtha & Solvents	17 Petroleum refineries	841,990	561,587,596
8	Other Hydrocarbons	20 Petrochemical mfg	419,025	216,418,605
9	Benzene & Toluene	20 Petrochemical mfg	356,485	148,762,965
10	Petro. Products NEC	17 Petroleum refineries	317,666	189,558,043
11	I&S Pipe & Tube	30. Iron and steel mills and ferroalloy mfg	209,745	373,525,063
12	Alcohols	10. Food, beverage, and tobacco mfg	208,359	245,565,199
13	Nitrogen Func. Comp.	22. Other basic organic chemical mfg	154,404	798,177,278
14	Lube Oil & Greases	18 Petroleum lubricating oil and grease mfg	122,480	81,691,289
15	Acyclic Hydrocarbons	20 Petrochemical mfg	108,680	158,201,222
16	Organic Comp. NEC	22. Other basic organic chemical mfg	69,095	504,594,429
17	Carboxylic Acids	22. Other basic organic chemical mfg	67,120	208,940,029
18	I&S Bars & Shapes	30. Iron and steel mills and ferroalloy mfg	56,139	89,355,851
19	Metallic Salts	25 Other chemical mfg	33,566	83,971,498
20	Ammonia	25. Other chemical mfg	29,450	4,348,083
21	Chemical Additives	25. Other chemical mfg	14,162	46,361,873

Note: This table includes export commodities more than 10,000 short tons. The sum of these commodities account for more than 99% of the total quantity of domestic export shipped from Port of Beaumont.

Table E-9. Summary table of domestic and foreign imports to ports of Port Arthur and Beaumont, 2008.

I-O Model Sector	Domestic Import	Foreign Import	Total Import
3 Sand, gravel, clay and ceramic and refractory minerals	1,536,322	7,760,271	9,296,593
5 Oil and gas extraction and all other mining	197,761,172	9,575,544,067	29,773,305,239
10 Food, beverage, and tobacco mfg	23,670,277	5,137,556	48,807,833
14 Pulp mills	0	137,716,983	137,716,983
16 Other paper and printing	0	2,497,441	2,497,441
17 Petroleum refineries	5,034,173,615	2,339,575,081	7,373,748,696
18 Petroleum lubricating oil and grease mfg	343,325,881	0	343,325,881
19 All other petroleum and coal products mfg	16,671,881	0	16,671,881
20 Petrochemical mfg	1,040,751,138	6,965,000	1,047,716,138
21. Alkalies and chlorine mfg	21,129,323	0	21,129,323
22 Other basic organic chemical mfg	385,424,408	94,944,101	480,368,509
25 Other chemical mfg	501,356,669	309,383,070	810,739,739
30. Iron and steel mills and ferroalloy mfg	0	123,279,794	123,279,794
31 Other primary metal and fabricated metal product mfg	27,396,011	141,985,633	169,381,644
33 Other machinery and equipment mfg	0	624,976,278	624,976,278
51 Government and Non-NAICS	897,362,720	0	897,362,720
Total	8,490,559,418	33,389,765,275	41,880,324,693

Table E-10. Summary table of domestic and foreign exports from ports of Port Arthur and Beaumont, 2008.

I-O Model Sector	Domestic Export	Foreign Export	Total Export
1. Agriculture, forestry and fishing	0	642,447,599	642,447,599
5 Oil and gas extraction and all other mining	1,619,673,758	0	1,619,673,758
10 Food, beverage, and tobacco mfg	245,565,199	1,983,788	247,548,987
12. Wood product mfg	0	2,103,800	2,103,800
14 Pulp mills	0	22,241,187	22,241,187
16 Other paper and printing	0	13,518,800	13,518,800
17 Petroleum refineries	6,891,939,849	3,184,013,182	10,075,953,031
18 Petroleum lubricating oil and grease mfg	555,448,744	0	555,448,744
20 Petrochemical mfg	624,055,096	0	624,055,096
21. Alkalies and chlorine mfg	15,572,535	383,605,629	399,178,164
22. Other basic organic chemical mfg	1,511,711,736	743,446,209	2,255,157,945
24. Fertilizer mfg	0	133,763,067	133,763,067
25 Other chemical mfg	217,478,922	143,374,523	360,853,445
30. Iron and steel mills and ferroalloy mfg	462,880,914	0	462,880,914
33 Other machinery and equipment mfg	0	17,688,580	17,688,580
Total	12,144,326,753	5,288,186,364	17,432,513,117

APPENDIX F. INPUT/OUTPUT TABLES

Table F-1. Input-output table for the Port Arthur MSA, 2008.

	Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	Agriculture, forestry and fishing	6		0	0	0	0	0	0	1	8	0	3			0	2	0		0	1		3	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
2	Coal mining																																								
3	Sand, gravel, clay and ceramic and refractory minerals	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
4	Support activities for oil and gas operations	0		0	2	2	0	0	0	0	0	0	0			0	0	11		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
5	Oil and gas extraction and all other mining	0		0	0	0	0	0	0	0	0	0	0			0	0	183		0	1		1	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
6	Electric power generation, transmission, and distribution	3		0	1	2	0	0	0	12	3	0	2			0	11	85		0	50		29	9		29	1			2	31	22		10	0	6	21	0	0	0.54	0
7	Natural gas distribution	0		0	0	0	0	0	0	0	0	0	0			0	1	19		0	19		6	1		1	0			0	2	1		0	0	0	0	0	0	0.02	0
8	Water, sewage and other systems	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.01	0
9	Construction	1		0	0	5	6	0	0	2	1	0	0			0	2	40		0	15		9	3		5	0			1	5	4		3	0	1	4	0	5	0.00	0
10	Food, beverage, and tobacco mfg	2		0	0	0	0	0	0	0	9	0	0			0	0	0		0	0		2	0		2	0			0	0	0		0	0	0	0	0	0	0.02	0
11	Textile and mills, apparel and leather product	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.02	0
12	Wood product mfg	0		0	0	0	0	0	0	56	0	0	13			0	5	0		0	0		2	0		0	0			0	0	0		2	1	1	1	0	1	0.00	0
13	All other miscellaneous wood product mfg																																								
14	Pulp mills																																								
15	Paperboard container and coated paper mfg	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
16	Other paper and printing	0		0	0	0	0	0	0	4	0	0	0			0	8	4		0	3		2	1		3	0			0	1	1		2	0	1	2	0	0	0.06	0
17	Petroleum refineries	11		0	4	2	7	0	0	110	1	0	1			0	7	2,118		14	1,169		438	116		102	1			1	6	5		4	0	11	6	2	11	0.00	27
18	Petroleum lubricating oil and grease mfg																																								
19	All other petroleum and coal products mfg	0		0	0	0	0	0	0	9	0	0	0			0	0	16		0	0		2	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
20	Petrochemical mfg	2		0	1	1	0	0	0	3	1	1	0			0	5	81		0	1,231		342	154		122	5			0	2	4		5	0	0	0	0	0	0.00	0
21	Alkalies and chlorine mfg																																								
22	Other basic organic chemical mfg	1		0	1	0	0	0	0	1	2	0	0			0	4	31		0	612		159	41		100	2			1	1	2		1	0	0	0	0	0	0.01	0
23	Synthetic rubber mfg	0		0	0	0	0	0	0	4	0	0	0			0	0	1		0	5		4	0		5	0			0	0	0		2	0	0	0	0	0	0.00	0
24	Fertilizer mfg																																								
25	Other chemical mfg	1		0	1	0	0	0	0	4	1	1	0			0	3	10		0	21		15	8		60	3			0	2	3		5	0	0	0	0	0	0.03	0
26	Plastics and rubber products mfg	0		0	1	0	0	0	0	16	2	0	0			0	2	2		0	0		10	0		11	1			0	0	2		9	1	2	2	0	0	0.01	0
27	Lime and gypsum product mfg																																								
28	Ground or treated mineral and earth mfg																																								
29	Other nonmetallic mineral product mfg	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
30	Iron and steel mills and ferroalloy mfg	0		0	1	0	0	0	0	1	0	0	0			0	0	0		0	0		0	0		0	0			0	19	27		9	0	0	0	0	0	0.02	0
31	Other primary metal and fabricated metal product mfg	0		0	1	0	0	0	0	11	1	0	0			0	1	2		0	1		2	0		2	0			0	5	17		11	0	0	0	0	0	0.47	0
32	Motor vehile mfg																																								
33	Other machinery and equipment mfg	1		0	10	2	2	0	0	125	2	0	2			0	9	15		1	13		33	6		20	2			1	17	30		244	1	8	9	0	4	6.67	3
34	Miscellaneous mfg	0		0	0	0	0	0	0	5	0	0	0			0	0	0		0	0		1	0		0	0			0	0	0		1	0	0	0	0	0	0.00	0
35	Wholesale trade	3		0	4	1	1	0	0	49	8	1	3			1	14	140		0	87		41	9		63	2			2	32	31		49	1	20	10	0	1	0.23	2
36	Retail trade	0		0	1	0	0	0	0	127	0	0	0			0	0	31		0	29		17	3		10	0			0	0	1		6	0	2	6	0	0	0.00	2
37	Air transportation	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.01	0
38	Rail transportation	1		0	1	0	7	0	0	3	2	0	1			0	3	14		0	22		13	2		7	0			1	19	4		2	0	0	0	0	0	0.03	2
39	Water transportation	1		0	0	0	0	0	0	2	1	0	0			0	0	16		0	4		3	0		1	0			0	4	2		0	0	0	0	0	0	0.00	0
40	Truck transportation	1		0	1	0	1	0	0	16	3	0	1			0	3	23		0	15		8	2		7	0			2	9	6		6	0	2	5	0	0	0.34	4
41	Other transportation	0		0	0	0	0	0	0	2	1	0	0			0	2	15		0	3		2	1		3	0			1	1	3		3	0	20	21	0	2	11.10	9
42	Pipeline transportation	0		0	0	0	4	2	0	0	0	0	0			0	0	194		0	3		1	0		1	0			0	0	0		0	0	0	0	0	0	0.00	0
43	Information and Communication	0		0	2	1	1	0	0	24	1	0	1			0	2	17		0	12		6	3		13	0			1	2	7		21	0	9	14	0	0	0.50	1
44	Finance, insurance, real estate, and leasing	6		0	11	5	2	0	0	34	2	0	1			0	4	25		0	35		10	6		9	1			1	3	14		12	1	18	48	0	6	3.54	3
45	Imputed rental for owner-occupied dwellings	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	0	0	0	0.00	0
46	Waste management and remediation services	0		0	1	0	0	0	0	2	0	0	0			0	1	7		0	3		4	1		2	0			0	2	1		1	0	1	2	0	0	1.30	0
47	Other business services	2		0	27	8	9	0	0	210	14	2	4			0	24	221		1	182		87	45		208	4			6	34	63		101	3	80	94	0	6	3.92	10
48	Health, education & social services	0		0	0	0	0	0	0	0	0	0	0			0	0	0		0	0		0	0		0	0			0	0	0		0	0	0	2	0	0	0.00	0
49	Accommodations, food services, and amusements	0		0	2	0	3	0	0	8	1	0	1			0	3	27		0	8		4	2		2	0			0	1	6		4	0	4	6	0	1	0.04	0
50	Personal services	0		0	0	0	0	0	0	3	0	0	0			0	0	2		0	1		1	0		0	0			0	1	1		0	0	2	1	0	0	0.04	0
51	Government and Non-NAICS	1		0	2	1	0	0	0	4	1	0	0			0	8	30		0	15		11	2		20	0			1	56	19		5	0	12	12	0	1	8.10	5
	HH	37		2	63	44	133	10	2	1,407	26	6	34			2	63	760		6	218		139	98		303	18			22	55	315		310	15	390	699	2	45	10.80	68
	OVA	32		1	54	89	348	13	1	139	8	2	18			0	36	310		3	982		91	45		263	14			11	43	178		83	4	281	386	0	59	10.43	23
	Other	1		0	1	0	0	0	0	7	1	0	0			0	3	75		0	45		18	5		10	0			0	16	6		2	0	4	4	0	1	2.19	2
	Foreign Trade	10		1	5	7	33	16	0	78	16	3	7			0	12	14,797		1	294		116	29		81	4			3	49	78		56	3	4	6	0	2	1.78	2
	Domestic Trade	84		1	81	35	75	18	0	868	155	11	44			7	191	15,793		8	1,569		685	210		761	39			39	300	517		514	19	150	222	1	27	26.69	34
	OUTPUT	208		6	279	210	632	61	4	3,346	271	28	138			12	429	35,115		37	6,672		2,317	806		2,225	101			97	721	1,370		1,485	53	1,031	1,586	7	173	88.93	199

Table F-1. Input-output table for the Port Arthur MSA, 2008 (Continued).

	Sector	41	42	43	44	45	46	47	48	49	50	51	HH	OVA	Other	Foreign Trade	Domestic Trade	OUTPUT
1	Agriculture, forestry and fishing	0	0	0	0	0	0	0	0	1	0	0	10	1	0	14	157	208
2	Coal mining																	
3	Sand, gravel, clay and ceramic and refractory minerals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	6
4	Support activities for oil and gas operations	0	0	0	0	0	0	0	0	0	0	0	0	0	237	1	26	279
5	Oil and gas extraction and all other mining	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	15	210
6	Electric power generation, transmission, and distribution	1	1	3	11	0	1	15	15	20	2	3	174	30	0	2	22	632
7	Natural gas distribution	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	61
8	Water, sewage and other systems	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	4
9	Construction	0	6	5	6	40	0	7	3	3	0	14	0	1,155	1,994	0	0	3,346
10	Food, beverage, and tobacco mfg	0	0	0	0	0	0	0	4	10	0	0	98	7	0	15	121	271
11	Textile and mills, apparel and leather product	0	0	0	0	0	0	0	0	0	0	0	8	1	0	6	11	28
12	Wood product mfg	0	0	1	1	3	0	0	0	1	0	0	1	5	2	7	32	138
13	All other miscellaneous wood product mfg																	
14	Pulp mills																	
15	Paperboard container and coated paper mfg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	12
16	Other paper and printing	0	0	2	1	1	0	4	2	1	0	0	5	6	1	3	371	429
17	Petroleum refineries	8	43	3	1	0	5	29	4	6	1	20	175	110	0	3,218	27,319	35,115
18	Petroleum lubricating oil and grease mfg																	
19	All other petroleum and coal products mfg	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	4	37
20	Petrochemical mfg	0	0	1	0	0	0	3	15	0	1	0	51	16	7	441	4,173	6,672
21	Alkalies and chlorine mfg																	
22	Other basic organic chemical mfg	0	0	0	0	0	0	1	3	2	0	1	17	8	0	765	559	2,317
23	Synthetic rubber mfg	0	0	0	0	0	0	1	1	0	0	0	3	2	0	292	483	806
24	Fertilizer mfg																	
25	Other chemical mfg	0	0	1	0	0	0	2	9	0	0	0	34	11	6	201	1,821	2,225
26	Plastics and rubber products mfg	0	0	1	0	1	0	2	3	2	0	1	10	8	0	9	1	101
27	Lime and gypsum product mfg																	
28	Ground or treated mineral and earth mfg																	
29	Other nonmetallic mineral product mfg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	94	97
30	Iron and steel mills and ferroalloy mfg	0	0	0	0	0	0	0	0	0	0	0	0	1	0	170	489	721
31	Other primary metal and fabricated metal product mfg	0	0	1	0	0	0	1	0	0	0	0	4	5	10	138	1,155	1,370
32	Motor vehile mfg																	
33	Other machinery and equipment mfg	2	4	17	2	2	6	37	7	4	2	7	164	116	265	277	6	1,485
34	Miscellaneous mfg	0	0	0	0	1	0	0	3	0	0	0	22	10	1	6	1	53
35	Wholesale trade	0	2	5	3	2	1	9	13	10	1	2	217	49	34	109	0	1,031
36	Retail trade	0	1	0	1	9	0	5	4	3	1	0	1,218	1	47	0	60	1,586
37	Air transportation	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	7
38	Rail transportation	0	0	0	0	0	0	1	0	1	0	1	6	4	4	21	29	173
39	Water transportation	0	0	0	0	0	0	4	0	0	0	1	7	3	0	31	6	89
40	Truck transportation	0	0	1	0	1	1	3	2	2	0	1	38	12	4	15	0	199
41	Other transportation	3	1	6	3	0	3	16	4	3	1	1	24	26	0	16	14	222
42	Pipeline transportation	0	0	0	0	0	0	0	0	0	0	2	2	1	0	8	0	219
43	Information and Communication	1	2	102	13	2	3	63	19	11	3	2	161	98	6	8	199	833
44	Finance, insurance, real estate, and leasing	2	3	19	94	84	6	90	59	24	5	9	479	54	0	48	0	1,235
45	Imputed rental for owner-occupied dwellings	0	0	0	0	0	0	0	0	0	0	0	1,302	0	0	0	0	1,302
46	Waste management and remediation services	0	0	1	5	1	21	2	2	2	0	2	17	39	0	1	142	263
47	Other business services	4	18	94	71	36	17	272	98	69	12	22	286	325	81	32	0	2,891
48	Health, education & social services	0	0	0	0	0	0	2	17	0	0	0	1,285	35	0	0	481	1,825
49	Accommodations, food services, and amusements	0	0	15	9	1	4	44	11	16	2	2	607	56	0	1	0	849
50	Personal services	0	0	1	1	0	1	5	3	3	2	1	153	19	0	0	0	203
51	Government and Non-NAICS	1	1	8	11	1	3	17	13	10	1	6	223	1,079	0	209	3	1,804
	HH	137	49	124	335	0	80	1,450	971	273	86	1,393						
	OVA	47	22	123	398	899	48	250	160	139	44	194						
	Other	1	2	4	4	0	4	8	12	3	0	2						
	Foreign Trade	1	15	6	3	5	3	14	18	11	2	17						
	Domestic Trade	13	49	290	260	212	52	531	350	216	34	96						
	OUTPUT	222	219	833	1,235	1,302	263	2,891	1,825	849	203	1,804						71,354

Table F-2. 2008 U.S. input-output table.

	Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	Agriculture, forestry and fishing	74,095	98	17	287	497	4	0	0	3,112	180,753	945	15,620	232	567	1	5,864	1	1	0	122	0	1,022	6	30	454	1,226
2	Coal mining	188	1,853	35	145	598	10,091	0	0	0	718	31	3	0	29	53	496	115	1	8	112	16	61	3	13	97	36
3	Sand, gravel, clay and ceramic and refractory minerals	0	20	105	33	275	12	21	16	2,067	3	0	0	0	0	0	294	173	0	14	1	0	2	0	4	226	0
4	Support activities for oil and gas operations	5	9	4	441	4,411	129	226	0	129	30	1	2	0	0	1	4	1,774	3	3	10	2	11	0	9	31	4
5	Oil and gas extraction and all other mining	1,804	1,235	628	37	13,337	18,213	31,372	6	7,509	201	42	57	1	19	52	296	248,652	644	951	2,110	407	2,247	69	1,327	5,370	163
6	Electric power generation, transmission, and distribution	4,361	498	280	268	5,193	5	19	27	5,438	10,453	1,218	1,118	49	135	858	5,243	1,571	21	156	1,448	1,060	1,445	118	676	8,623	2,820
7	Natural gas distribution	1,216	299	191	725	3,060	0	72	47	1,490	8,038	892	380	15	224	420	4,223	3,270	25	238	4,661	423	2,606	91	2,700	2,683	780
8	Water, sewage and other systems	173	0	0	3	9	11	1	0	107	104	9	6	1	2	6	31	10	1	1	7	1	19	1	1	77	23
9	Construction	1,090	0	0	2	13,164	3,367	35	715	1,081	2,247	205	274	44	44	293	1,198	738	9	60	394	52	441	46	158	1,853	627
10	Food, beverage, and tobacco mfg	24,641	0	0	7	44	0	0	0	14	186,837	1,020	38	0	28	8	1,130	23	27	27	560	1	951	21	1	4,514	321
11	Textile and mills, apparel and leather product	319	5	0	7	31	0	1	0	1,609	440	10,371	263	0	1	307	1,823	11	1	34	71	3	56	6	2	967	1,192
12	Wood product mfg	491	1	0	11	79	1	53	0	36,923	426	2	13,684	627	427	9	3,036	2	0	0	0	0	141	0	0	64	394
13	All other miscellaneous wood product mfg	20	0	1	13	22	0	0	0	324	43	22	130	34	1	1	19	0	0	0	1	0	8	0	9	42	22
14	Pulp mills	0	0	0	0	0	0	0	0	5	0	0	0	0	34	418	3,263	0	0	0	0	0	0	0	0	0	0
15	Paperboard container and coated paper mfg	136	23	10	337	548	11	8	2	2,392	23,748	389	208	25	4	969	5,390	32	31	52	32	67	243	87	72	5,149	2,376
16	Other paper and printing	221	32	14	131	454	91	15	12	2,282	7,265	416	156	6	40	24,459	24,037	132	7	135	54	16	111	16	90	2,679	1,281
17	Petroleum refineries	18,467	245	124	567	4,264	3,696	54	76	49,241	2,528	220	587	11	103	668	3,080	32,501	4,392	8,395	24,412	1,541	18,296	1,304	1,749	29,451	1,442
18	Petroleum lubricating oil and grease mfg	93	123	4	781	1,516	2	1	0	1,446	924	16	7	0	0	1	12	14	24	7	6	1	14	4	1	341	114
19	All other petroleum and coal products mfg	62	4	3	89	125	20	20	0	16,576	31	20	5	0	1	5	23	1,173	13	245	65	5	466	3	6	224	72
20	Petrochemical mfg	1,836	3	1	81	3,167	24	5	1	1,012	1,108	2,023	156	5	29	402	1,189	1,441	232	155	32,962	49	17,843	2,196	41	25,390	6,568
21	Alkalies and chlorine mfg	33	0	0	3	31	0	0	0	19	46	40	4	0	78	8	391	73	5	20	365	68	797	16	5	2,362	212
22	Other basic organic chemical mfg	488	11	1	175	1,043	5	5	5	303	2,217	384	82	2	76	102	1,580	474	68	59	12,971	19	6,470	486	9	27,883	3,769
23	Synthetic rubber mfg	18	0	0	2	7	0	0	0	35	36	24	2	0	0	5	17	2	0	0	26	0	21	9	0	406	3,059
24	Fertilizer mfg	5,817	0	0	0	25	0	0	0	3,293	7	17	1	0	0	3	9	6	9	0	592	5	539	10	3,991	1,355	103
25	Other chemical mfg	16,256	19	5	649	3,154	10	42	7	6,837	10,086	18,989	1,427	50	172	3,760	9,796	1,155	170	165	4,127	381	4,930	744	341	133,475	50,597
26	Plastics and rubber products mfg	843	335	63	508	1,566	40	100	1	20,266	16,599	526	559	4	4	1,097	2,098	95	49	52	15	13	1,263	5	26	9,474	7,831
27	Lime and gypsum product mfg	9	0	0	0	148	4	21	0	3,226	13	0	258	1	17	19	109	43	0	1	0	0	1	0	0	3	49
28	Ground or treated mineral and earth mfg	0	17	1	403	324	5	9	0	206	11	0	1	0	0	0	2	67	0	60	0	0	1	0	152	370	1
29	Other nonmetallic mineral product mfg	21	66	5	348	703	46	79	13	61,261	5,627	91	660	5	1	2	33	75	0	630	3	12	76	0	6	733	580
30	Iron and steel mills and ferroalloy mfg	12	123	42	931	2,088	1	6	0	1,883	357	54	66	1	1	56	59	20	1	20	17	8	35	1	2	280	143
31	Other primary metal and fabricated metal product mfg	973	292	43	1,631	6,734	117	246	9	77,571	22,640	756	1,379	42	43	1,091	2,851	473	55	156	134	159	826	62	146	6,613	3,562
32	Motor vehile mfg	4	1	0	3	8	2	1	0	94	12	1	2	0	0	2	6	0	0	0	0	0	2	0	0	9	5
33	Other machinery and equipment mfg	2,874	1,047	155	2,371	5,768	1,194	551	67	69,040	8,150	931	1,377	40	16	1,216	4,594	283	41	378	357	329	1,700	88	201	7,229	3,899
34	Miscellaneous mfg	147	9	4	80	247	11	9	1	12,599	327	386	235	5	3	46	118	13	1	11	9	3	264	3	3	535	291
35	Wholesale trade	11,375	518	80	1,562	4,529	563	167	23	48,245	53,564	6,037	4,940	216	224	6,774	13,374	4,695	157	643	4,058	328	3,816	236	601	39,967	6,435
36	Retail trade	309	102	6	225	968	27	7	8	66,122	1,441	109	131	0	0	60	139	547	143	54	709	0	809	37	1	3,298	121
37	Air transportation	147	5	3	182	76	115	26	3	1,660	1,295	144	141	9	5	148	503	94	3	8	148	5	130	12	6	619	321
38	Rail transportation	1,460	943	55	246	806	4,864	44	10	2,145	7,307	82	781	33	90	1,037	1,956	313	15	53	675	43	751	38	270	2,696	1,097
39	Water transportation	882	65	7	60	204	199	1	1	930	3,412	12	7	0	3	17	129	271	26	70	103	14	158	4	45	293	18
40	Truck transportation	4,309	456	154	615	1,996	666	61	16	16,560	20,630	1,565	1,967	65	81	1,388	3,307	795	40	162	740	33	769	47	1,449	4,519	1,276
41	Other transportation	823	49	8	114	260	343	44	2	1,477	2,570	354	518	83	16	376	1,281	333	10	39	104	12	140	24	82	1,143	600
42	Pipeline transportation	27	13	3	64	1,583	4,724	8,104	2	524	60	137	7	0	0	7	26	7,081	53	133	176	3	124	8	7	522	63
43	Information and Communication	798	179	81	1,292	3,224	1,465	168	179	28,843	8,256	1,494	982	72	38	924	2,889	675	46	114	662	95	727	101	172	10,242	2,040
44	Finance, insurance, real estate, and leasing	29,046	1,531	419	6,953	35,807	2,544	1,083	296	48,126	16,415	2,492	1,403	129	64	1,789	5,338	1,227	54	207	2,321	56	1,312	234	428	8,259	3,894
45	Imputed rental for owner-occupied dwellings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	Waste management and remediation services	34	16	10	128	137	53	13	10	1,304	1,180	104	82	11	20	76	341	134	6	13	87	13	202	9	10	766	283
47	Other business services	4,602	1,564	616	8,988	27,882	7,268	1,155	975	151,871	64,103	10,264	4,505	420	307	4,519	17,070	5,428	417	922	6,337	995	6,074	859	1,480	99,598	11,116
48	Health, education & social services	1,438	24	7	135	312	88	97	8	3,597	447	59	82	2	4	72	249	142	2	7	43	0	1	0	4	79	154
49	Accommodations, food services, and amusements	360	14	10	686	176	2,048	123	16	5,839	3,098	463	615	37	21	527	1,769	652	12	33	269	4	247	36	38	928	1,194
50	Personal services	75	10	1	8	69	9	64	36	1,609	239	58	32	5	5	31	131	51	1	6	45	6	48	5	17	200	72
51	Government and Non-NAICS	2,708	153	79	596	2,211	273	88	30	2,820	5,367	538	372	33	141	325	4,973	1,072	15	142	1,031	250	1,014	56	483	8,201	1,319
	HH	70,882	9,228	3,868	17,450	93,571	72,050	18,899	4,555	575,001	94,305	27,716	24,035	1,069	768	16,800	58,127	24,058	2,539	7,586	5,014	1,118	5,910	1,366	2,226	97,321	42,769
	OVA	92,807	8,562	1,326	15,016	181,685	191,166	25,382	3,282	55,619	90,215	9,452	5,778	530	285	2,104	26,886	12,673	1,857	4,013	22,882	549	3,933	645	1,101	118,825	27,157
	Other	3,726	86	16	209	625	574	293	11	4,715	8,108	318	928	27	56	384	1,626	3,186	145	296	1,131	61	943	69	100	3,646	790
	Foreign Trade	28,297	2,196	787	2,860	22,324	20,173	30,990	79	113,476	59,497	20,117	9,243	324	418	7,340	20,022	250,427	1,747	3,293	23,467	1,029	16,605	1,234	5,218	65,216	18,903
	Domestic Trade	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OUTPUT	410,814	32,085	9,273	68,464	451,083	346,328	119,780	10,551	1,519,875	933,535	121,561	95,294	4,265	4,643	81,037	242,448	608,267	13,118	29,831	155,644	9,256	106,618	10,413	25,512	745,297	213,184

Table F-2. 2008 U.S. input-output table (Continued).

	Sector	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1	Agriculture, forestry and fishing	0	0	4	1	7	0	26	209	32	1,461	8	1	2	0	4	0	58	1,671	242	37	994
2	Coal mining	112	21	544	4,367	436	8	30	3	9	13	0	0	18	0	2	0	10	88	0	1	89
3	Sand, gravel, clay and ceramic and refractory minerals	6	20	3,016	39	89	1	886	2	0	1	0	0	0	0	0	1	1	1	71	0	47
4	Support activities for oil and gas operations	4	1	17	29	176	11	221	16	6	4	1	1	3	2	6	12	17	4	7	2	15
5	Oil and gas extraction and all other mining	625	194	2,067	2,793	4,029	21	1,875	205	1,123	548	2,173	318	0	2,127	665	1,938	945	538	385	136	2,748
6	Electric power generation, transmission, and distribution	325	107	3,025	4,789	9,901	761	13,221	1,519	6,364	16,526	90	24	200	486	1,064	167	4,647	25,125	0	321	13,413
7	Natural gas distribution	563	102	2,733	3,352	4,396	719	4,157	485	1,716	1,558	7	2	82	160	181	145	2,465	2,616	0	164	2,612
8	Water, sewage and other systems	1	0	14	39	65	38	91	23	64	111	4	2	19	9	29	0	113	314	0	57	128
9	Construction	43	13	784	966	2,343	226	4,417	670	1,626	3,889	31	2,218	0	166	377	797	7,215	16,345	40,821	66	6,055
10	Food, beverage, and tobacco mfg	149	0	40	9	40	7	102	22	1,070	465	65	2	48	2	3	0	231	14	4	6	1,170
11	Textile and mills, apparel and leather product	2	0	171	14	118	1,694	2,791	2,264	912	1,496	1	1	62	16	8	8	217	140	80	151	415
12	Wood product mfg	13	0	532	14	267	890	2,807	6,766	1,482	1,035	2	795	2	148	27	0	1,866	2,719	3,777	20	407
13	All other miscellaneous wood product mfg	0	0	19	2	170	9	162	144	35	29	0	2	0	2	2	1	15	24	36	1	45
14	Pulp mills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
15	Paperboard container and coated paper mfg	9	8	1,099	369	2,361	1,081	6,677	2,421	2,325	1,135	70	38	2	142	141	39	866	1,086	172	244	2,232
16	Other paper and printing	544	6	555	135	955	216	4,357	854	8,646	6,637	80	78	28	344	176	57	22,561	13,501	371	163	18,118
17	Petroleum refineries	146	27	757	772	2,295	130	4,349	215	12,392	4,686	30,943	4,292	0	30,334	9,351	5,012	3,779	2,792	36	1,482	27,395
18	Petroleum lubricating oil and grease mfg	0	0	78	216	180	15	714	198	511	330	22	13	0	202	22	1	71	114	51	6	487
19	All other petroleum and coal products mfg	1	1	67	159	649	24	1,359	57	44	51	88	14	0	86	27	15	195	59	1,491	69	295
20	Petrochemical mfg	4	1	287	171	970	179	3,828	1,093	278	139	196	44	1	213	79	33	451	188	56	53	1,548
21	Alkalies and chlorine mfg	4	0	516	10	120	4	119	27	8	2	0	1	0	5	5	0	25	11	122	13	129
22	Other basic organic chemical mfg	5	8	908	142	714	108	1,662	450	242	63	34	42	4	76	23	9	256	278	101	120	947
23	Synthetic rubber mfg	0	0	30	6	30	13	1,096	1,647	10	7	0	0	0	2	1	0	9	4	3	1	55
24	Fertilizer mfg	0	0	31	10	34	1	72	12	183	31	0	2	0	0	0	0	3	22	703	0	196
25	Other chemical mfg	33	3	2,286	1,509	8,467	1,917	34,061	7,769	1,800	1,090	35	125	11	255	197	14	3,966	1,538	555	250	12,130
26	Plastics and rubber products mfg	3	1	742	182	2,387	8,370	32,399	8,647	5,689	4,569	9	21	8	1,572	380	78	3,224	1,487	1,681	195	6,175
27	Lime and gypsum product mfg	20	10	341	863	33	5	251	478	11	91	0	1	0	0	0	0	186	60	324	19	320
28	Ground or treated mineral and earth mfg	148	90	581	322	31	8	142	71	1	2	0	0	0	0	0	0	3	2	37	0	4
29	Other nonmetallic mineral product mfg	67	10	13,598	821	1,567	2,840	7,222	474	485	792	4	9	1	27	19	6	1,336	396	2,120	120	1,842
30	Iron and steel mills and ferroalloy mfg	5	51	240	8,738	37,094	945	35,755	2,821	78	43	11	114	34	18	17	7	445	202	45	47	554
31	Other primary metal and fabricated metal product mfg	33	51	3,083	9,666	123,756	8,964	171,382	12,281	2,867	2,139	839	545	2,644	1,430	1,005	559	9,441	1,619	3,569	1,031	7,149
32	Motor vehile mfg	0	0	3	4	32	1,404	1,477	6	13	13	3	2	4	5	41	1	34	6	3	160	231
33	Other machinery and equipment mfg	61	59	2,066	3,053	17,487	123,332	363,128	4,426	10,347	8,560	2,327	1,633	2,876	4,203	2,240	551	26,036	4,422	2,295	2,138	43,394
34	Miscellaneous mfg	6	0	215	38	622	509	4,485	9,130	1,375	1,251	14	12	11	40	50	7	751	801	4,430	325	2,290
35	Wholesale trade	149	44	5,399	10,308	29,101	20,226	133,372	11,952	47,431	16,525	1,364	848	177	3,818	1,270	420	12,890	13,735	3,550	841	17,731
36	Retail trade	19	1	97	12	256	231	8,908	2,212	1,912	5,486	14	48	0	2,282	390	115	597	1,510	8,524	59	5,449
37	Air transportation	3	6	234	162	1,078	204	2,922	487	1,851	494	8	20	74	530	143	3	3,599	4,255	30	390	7,935
38	Rail transportation	271	57	1,719	3,912	2,743	786	3,000	585	265	193	61	257	13	2,682	36	12	473	193	223	26	1,060
39	Water transportation	25	14	211	571	779	20	483	39	101	43	246	41	1	215	69	54	48	35	64	14	4,427
40	Truck transportation	589	222	5,407	3,066	6,171	2,665	15,820	3,401	4,270	8,053	306	297	273	10,456	573	85	2,898	1,227	1,645	409	5,861
41	Other transportation	45	20	1,030	387	1,967	323	5,758	1,216	31,982	22,647	9,800	964	5,616	15,353	5,352	96	10,489	9,463	62	1,143	19,913
42	Pipeline transportation	0	0	0	18	32	0	128	2	178	55	503	105	0	572	81	50	9	16	3	30	47
43	Information and Communication	61	45	1,942	961	7,949	1,442	67,019	4,332	25,854	28,226	2,193	422	468	3,792	1,845	473	350,665	77,223	2,834	2,124	150,817
44	Finance, insurance, real estate, and leasing	95	87	3,405	1,562	19,555	1,570	46,981	9,688	60,617	116,149	9,084	7,572	3,940	12,150	6,035	992	77,778	661,359	223,605	5,183	218,931
45	Imputed rental for owner-occupied dwellings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	Waste management and remediation services	9	3	178	340	735	55	1,100	327	812	1,466	21	26	604	110	406	63	1,700	13,244	445	7,633	2,192
47	Other business services	402	231	10,703	8,006	44,731	8,678	203,642	21,086	142,508	116,366	5,076	3,695	2,277	18,160	8,316	3,344	199,258	254,532	33,279	7,599	408,852
48	Health, education & social services	1	3	114	36	412	9	553	220	1,661	4,655	74	139	0	177	54	53	2,508	4,953	15,226	184	7,306
49	Accommodations, food services, and amusements	21	32	913	328	3,873	207	7,555	1,834	6,455	7,251	4,206	317	23	251	424	21	30,195	30,920	608	1,655	63,256
50	Personal services	5	2	164	138	614	26	822	106	2,377	1,382	6	60	19	343	613	50	2,108	2,417	0	263	7,009
51	Government and Non-NAICS	142	36	1,433	10,658	11,472	1,883	9,035	1,110	17,852	13,563	5,302	266	3,694	6,648	2,411	174	14,336	33,010	1,649	1,225	20,178
	HH	1,423	466	31,407	11,247	122,489	32,876	371,258	83,364	470,393	550,766	42,589	17,234	6,205	99,748	122,580	10,489	330,484	933,298	0	23,230	1,539,918
	OVA	1,575	1,047	18,217	8,540	67,768	9,376	113,866	31,390	338,076	356,167	12,931	22,955	6,027	33,333	51,302	4,671	295,452	1,179,115	827,771	13,922	373,604
	Other	24	6	290	2,217	2,432	731	3,427	648	3,836	2,972	1,877	205	739	2,058	691	219	4,405	8,627	2,697	1,782	6,599
	Foreign Trade	872	295	8,631	12,487	62,126	67,790	255,958	23,334	18,607	15,613	10,570	2,705	2,245	12,455	4,485	3,454	29,281	23,939	12,374	2,813	50,677
	Domestic Trade	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OUTPUT	8,662	3,401	131,945	118,557	608,102	303,546	1,956,924	262,740	1,238,780	1,326,841	143,285	68,527	38,457	267,208	223,219	34,301	1,460,608	3,331,257	1,198,174	77,920	3,065,393

Table F-2. 2008 U.S. input-output table (Continued).

	Sector	48	49	50	51	HH	OVA	Other	Foreign Trade	Domestic Trade	OUTPUT
1	Agriculture, forestry and fishing	363	5,657	6	23	56,615	2,262	1,067	55,110	0	410,814
2	Coal mining	9	39	2	8,619	28	125	0	2,809	0	32,085
3	Sand, gravel, clay and ceramic and refractory minerals	8	3	0	530	102	5	42	1,135	0	9,273
4	Support activities for oil and gas operations	5	13	3	100	14	19	60,341	174	0	68,464
5	Oil and gas extraction and all other mining	792	1,183	165	14,265	9,719	3,690	40,752	18,315	0	451,083
6	Electric power generation, transmission, and distribution	15,387	21,588	2,124	2,816	134,674	13,501	0	1,062	0	346,328
7	Natural gas distribution	4,818	4,154	364	3,905	30,703	8,801	0	50	0	119,780
8	Water, sewage and other systems	696	299	46	485	5,317	1,848	0	136	0	10,551
9	Construction	5,127	4,005	444	15,439	0	363,237	1,014,352	65	0	1,519,875
10	Food, beverage, and tobacco mfg	23,561	74,224	58	331	541,266	15,966	143	54,326	0	933,534
11	Textile and mills, apparel and leather product	1,807	981	437	179	69,781	2,756	2,120	15,418	0	121,561
12	Wood product mfg	758	2,011	120	572	921	2,305	4,083	4,585	0	95,294
13	All other miscellaneous wood product mfg	66	237	4	4	1,627	494	17	405	0	4,265
14	Pulp mills	0	0	0	0	0	0	0	922	0	4,643
15	Paperboard container and coated paper mfg	1,675	3,909	300	211	3,212	1,682	34	5,158	0	81,037
16	Other paper and printing	13,276	7,025	1,133	997	29,897	26,532	1,440	19,610	0	242,448
17	Petroleum refineries	3,987	6,103	568	17,269	135,391	44,336	0	52,016	0	608,267
18	Petroleum lubricating oil and grease mfg	173	251	33	135	3,224	482	26	115	0	13,118
19	All other petroleum and coal products mfg	184	378	7	860	1,008	1,793	25	1,569	0	29,831
20	Petrochemical mfg	7,571	276	335	237	21,415	3,788	337	13,954	0	155,644
21	Alkalies and chlorine mfg	511	7	8	263	369	243	6	2,152	0	9,256
22	Other basic organic chemical mfg	2,492	357	99	377	4,461	2,266	43	31,644	0	106,618
23	Synthetic rubber mfg	176	10	5	20	231	47	3	3,334	0	10,413
24	Fertilizer mfg	76	96	6	286	251	676	2	7,037	0	25,512
25	Other chemical mfg	62,222	2,297	3,012	1,029	194,351	29,695	3,607	103,729	0	745,297
26	Plastics and rubber products mfg	7,048	5,536	966	2,318	22,816	9,488	805	22,956	0	213,184
27	Lime and gypsum product mfg	150	574	1	575	63	79	14	272	0	8,662
28	Ground or treated mineral and earth mfg	4	5	1	13	73	3	11	219	0	3,401
29	Other nonmetallic mineral product mfg	1,964	2,762	395	3,078	9,075	1,191	123	8,525	0	131,945
30	Iron and steel mills and ferroalloy mfg	289	326	143	211	166	326	181	23,447	0	118,557
31	Other primary metal and fabricated metal product mfg	2,019	6,301	1,513	4,887	12,257	13,238	10,953	64,280	0	608,102
32	Motor vehile mfg	10	21	4	46	126,125	7,900	91,612	74,228	0	303,546
33	Other machinery and equipment mfg	8,301	5,149	2,993	7,784	156,299	143,881	385,676	508,315	0	1,956,924
34	Miscellaneous mfg	15,099	1,924	1,461	628	100,591	15,536	40,110	45,668	0	262,740
35	Wholesale trade	25,883	22,741	3,119	4,823	382,091	42,719	82,724	130,399	0	1,238,780
36	Retail trade	4,346	3,826	1,386	21	1,164,277	206	39,281	0	0	1,326,841
37	Air transportation	2,089	1,513	297	945	64,303	8,548	1,134	34,218	0	143,285
38	Rail transportation	631	740	38	1,038	6,764	2,479	2,175	8,284	0	68,527
39	Water transportation	102	117	4	665	6,425	3,478	13	13,225	0	38,457
40	Truck transportation	5,809	5,221	697	2,515	69,521	14,384	10,742	20,961	0	267,208
41	Other transportation	7,342	4,755	1,329	1,555	27,322	12,645	437	13,405	0	223,219
42	Pipeline transportation	72	33	1	3,237	3,670	830	0	1,177	0	34,301
43	Information and Communication	57,132	29,138	8,951	5,847	323,776	124,695	88,979	25,644	0	1,460,608
44	Finance, insurance, real estate, and leasing	219,959	77,334	15,245	24,938	1,177,623	61,059	0	97,338	0	3,331,257
45	Imputed rental for owner-occupied dwellings	0	0	0	0	1,198,174	0	0	0	0	1,198,174
46	Waste management and remediation services	2,546	3,186	509	2,367	15,660	16,979	0	160	0	77,920
47	Other business services	159,971	116,437	19,638	31,707	245,950	322,111	161,820	67,683	0	3,065,393
48	Health, education & social services	31,039	2,245	689	417	1,880,683	23,765	0	1,348	0	1,985,576
49	Accommodations, food services, and amusements	19,709	25,349	2,448	2,248	771,752	34,318	0	1,393	0	1,036,776
50	Personal services	3,689	4,247	2,585	1,334	172,974	9,396	0	23	0	215,604
51	Government and Non-NAICS	19,335	16,031	1,844	8,774	233,050	1,384,243	75	180,088	0	2,033,807
	HH	1,067,719	350,902	76,821	1,570,019	0	0	0	0	0	0
	OVA	126,137	188,463	57,308	253,500	0	0	0	0	0	0
	Other	8,356	3,798	508	2,308	0	0	0	0	0	0
	Foreign Trade	43,087	23,003	5,428	27,053	0	0	0	0	0	0
	Domestic Trade	0	0	0	0	0	0	0	0	0	0
	OUTPUT	1,985,575	1,036,776	215,604	2,033,808	0	0	0	0	0	27,507,784

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APPENDIX G. SUPPLY-DRIVEN INPUT-OUTPUT MODEL

When we use the pure supply-driven I-O model (Ghosh, 1958) for impact analysis, the Leontief production function is not likely to be intact in theory (this is the "joint stability" problem characterized by Chen and Rose, 1991). The Leontief production function, which has the following specification, assumes fixed proportions of inputs of production:

$$X_j = \min\left(\frac{z_{1j}}{a_{1j}}, \frac{z_{2j}}{a_{2j}}, \cdots, \frac{z_{nj}}{a_{nj}}, \frac{W_j}{a_{wj}}\right) \quad (1)$$

where j represents the sector in the I-O table; $z_{1j}, z_{2j}, \cdots, z_{nj}$ represent the intermediate inputs into each sector; W_j represents the sectoral value-added; and "a"s are the technical coefficients. Oosterhaven (1988) demonstrated how the supply-side calculation differs from applying the Leontief production function by examining the Taylor expansion of the Ghoshian supply-side model:

$$\Delta X = \Delta V (1 - A^s)^{-1} \quad (2)$$

where ΔX is gross output change; ΔV is the change in the extended value-added (which includes imports); A^s is the allocation coefficient matrix.

For illustration purpose, consider a simple example, which has one disrupted import commodity (e.g., Crude Oil) and one using sector of this commodity (e.g., Petroleum Refineries). The vector of ΔM, changes in imported commodities, has only one non-zero number, $\Delta m_{crudeoil,j}$, in which j represents the Petroleum Refining sector. The supply-side equation (2) can be written as:

$$\Delta X = \Delta M (1 - A^s)^{-1} = \Delta M\, \mathrm{I} + \Delta M\, A^s + \Delta M \left(A^s\right)^2 + \Delta M \left(A^s\right)^3 + \cdots \quad (3)$$

The first term of the Taylor expansion, $\Delta M\, \mathrm{I}$, is the direct output effect of the import disruption. In this case, since we assume that the only using sector of imported crude oil is sector j, Petroleum Refineries, it will be the only directly affected sector, and ΔX_j equals $\Delta m_{crudeoil,j}$. This means according to the supply-side model calculation, the direct output loss in the Petroleum Refineries sector simply equals the shortfall in the imported input (e.g., crude oil). However, according to the Leontief production function, the actual direct output loss in the Petroleum Refineries sector should be:

$$\Delta X_j = \Delta m_{crudeoil,j} \Big/ a_{m\_crudeoil,j} \quad (4)$$

where $a_{m\_crudeoil,j}$ is the technical coefficient of imported crude oil of the Petroleum Refineries sector, which equals the ratio of imported crude oil used as input over the total output of Sector j. Therefore, the direct output impact implied by the Leontief production function, equation (4), is larger than the direct effect

computed by the supply-side model ($\Delta m_{crudeoil,j}$) by the reciprocal of the technical coefficient of the imported input (e.g., $1/a_{m\_crudeoil,j}$ in this case).

Next, consider the indirect effects of the import disruption. The second term in the Taylor expansion, $\Delta M\ A^s$, calculates the first-round forward linkage effects resulting from the direct output impacts in the Petroleum Refineries sector. All the affected sectors in this round of calculation are the direct users of Petroleum Refineries product in the production process. $\Delta M\ A^s$ indicates that the first-round indirect effect on each sector equals the direct effect in the Petroleum Refineries sector (ΔM) times the corresponding allocation coefficient, i.e., the output loss in sector *i* equals the value of its losses of petroleum refineries product used as input. Once again, according to the Leontief production function, the reciprocal of the technical coefficient of petroleum refineries product input is missing in the calculation formula, i.e., the output loss in the first-round downstream sector *i* that uses petroleum refineries product as input should be:

$$\Delta X_i = \Delta X_j a^s_{ji}\left(1/a^D_{ji}\right) = \left(\Delta m_{crudeoil,j}/a_{m\_crudeoil,j}\right)a^s_{ji}\left(1/a^D_{ji}\right) \qquad (5)$$

where ΔX_i is the gross output impact on sector *i*; a^s_{ji} is the allocation coefficient of the Petroleum Refineries sector to sector *i*; a^D_{ji} is the technical coefficient of petroleum refineries product in sector *i*.

Equation (5) again differs from the first-round indirect effect implied by the supply-driven model, $\Delta m_{crudeoil,j} a^s_{ji}$, and the difference is $\left(1/a_{m\_crudeoil,j}\right)\left(1/a^D_{ji}\right)$.

Next, we would like to examine the relationship between the percentage disruption in the import commodity (Crude Oil in this case) and the percentage output impacts of the direct using sector (Petroleum Refineries sector in this case) and the downstream sectors. Equation (4) can be transformed to:

$$\Delta X_j = \frac{\Delta m_{crudeoil,j}}{a_{m\_crudeoil,j}} = \frac{\Delta m_{crudeoil,j}}{\frac{m_{crudeoil,j}}{X_j}} = \Delta m_{crudeoil,j}\% \cdot X_j \qquad (6)$$

where $m_{crudeoil,j}$ is the total imported crude oil used as input in the Petroleum Refineries sector. Equation (6) indicates that the direct output impact to the Petroleum Refineries sector according to the Leontief production function equals the original gross output of the Petroleum Refineries sector times the percentage reduction of the imported crude oil input. In other words, if the crude oil import is disrupted by 50%, the direct effect indicates that the gross output of the Petroleum Refineries sector is reduced by 50% as well.

Next, equation (5) can be transformed to:

$$\Delta X_i = \Delta X_j a^s_{ji}\left(1/a^D_{ji}\right) = \Delta X_j \cdot \frac{z_{ji}}{X_j} \cdot \frac{1}{\frac{z_{ji}}{X_i}} = \frac{\Delta X_j}{X_j} \cdot X_i = \Delta m_{crudeoil,j}\% \cdot X_i \qquad (7)$$

where z_{ji} is the intermediate input from the Petroleum Refineries sector that is used in sector i. Equation (7) indicates that the first-round output impact to sector i equals its original gross output times the percentage reduction in the imported crude oil. In other words, if the crude oil import is reduced by 50%, the direct effect of output reduction in the Petroleum Refineries sector is 50%, and the output impacts to the first-round customer sectors of Petroleum Refineries sector are also 50%. It seems that the calculations of the higher-order forward linkage effects will carry the 50% disruption effect to all the sectors. However, for each sector, the total output impact will be just 50%, since from the perspective of the purchasing sectors, when more than one input falls short by 50%, the output impact is still a 50% reduction.

Gruver (1989) pointed out that the production relations implied when the supply-driven model is applied in impact studies is actually a "perfect substitutability among all inputs" in each industry in production (Gruver, 1989; p. 443-444). This is the opposite assumption applied in the Leontief production function, which assumes zero substitutions among inputs. However, we know in practice, both perfect substitutions and zero substitutions among inputs are extreme cases. Therefore, the output impacts computed through the supply-driven model and through the Leontief production function tend to provide the lower- and upper-bound estimates of the impacts.

Chen and Rose (1991) and Rose and Allison (1989) examined the relationship between the demand-driven (Leontief) and supply-driven (Ghosh) models in terms of the joint stability of their respective coefficients. Even though it is impossible for the coefficients of both model versions to be constant, as is required, in a given application, a simulation exercise by Rose and Allison (1989) found the coefficient variation to be relatively small. Thus, rather than behaving like a perfect substitution production function, the Leontief production function behaved much more closely to its intended fixed-coefficient form. Thus, Gruver's insights are not sufficient to warrant avoiding the use of the Ghoshian model in general.

Dietzenbacher (1997) showed that "the supply-driven input-output model yields exactly the same results as the Leontief price model". This new interpretation of the supply-driven model provide the plausibility of using the supply-driven model in cases where the exogenous change are caused by price changes in primary factors only. However, this interpretation does not apply if the analyses are focused on the impacts of shortfalls of primary factors. Dietzenbacher stated that "in analyzing quantity effects by means of the Ghosh model, the Oosterhaven (1988) critique applies undiminishedly" (Dietzenbacher, 1977; p.635).

However, Gruver (1989), Klein (1953) and others have pointed out that in empirical I-O models, usually expressed in value terms rather than just pure quantity terms (i.e, instead of being expressed in quantities like tons, the entries are expressed in dollars), the production function is actually Cobb-Douglas, simply requiring fixed value shares (i.e., the price times quantity relationship is fixed for each coefficient, but this allows for the price to change if the quantity changes sufficient to leave the product of the two unchanged). Thus, it would seem that Dietzenbacher's finding supports the use of the supply-driven I-O model for value-based I-O models, where the change in the coefficient can be interpreted as either a price or quantity change.

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APPENDIX H. REVENUES BY SECTOR/CATEGORY OF PORT OF HOUSTON AND SABINE NECHES WATERWAY

Table H-1. Revenues by sector and category of Port of Houston.

	TOTAL
SURFACE TRANSPORTATION	
RAIL	$1,988,566
TRUCK	$1,591,416
PIPELINE	$594,975
MARITIME SERVICES	
TERMINAL EMPLOYEES	$794,032
TOWING	$29,359
PILOTS	$32,883
AGENTS	$11,838
SURVEYORS/CHANDLERS	$82,870
FORWARDERS	$351,297
WAREHOUSEMEN	$1,061,151
GOVERNMENT	NA
MARITIME SERVICES	$461,365
BARGE/BUNKERS	$329,246
DEPENDENT SHIPPERS/CONSIGNEES	NA
PORT OF HOUSTON AUTHORITY	$155,180
BANKING/INSURNACE	$600,502
TOTAL	$8,084,680

Source: Martin Associates (2007)

Table H-2. Revenues by sector and category of Sabine Neches Waterway.

Total Revenue Generated By Waterway Activity

IMPACT CATEGORIES	REVENUE (1,000)
SURFACE TRANSPORTATION	
RAIL	$125,040
TRUCK	$355,079
PIPELINE	$295,497
SUBTOTAL	**$775,616**
MARITIME SERVICES SECTOR	
TERMINAL EMPLOYEES	$983,875
TUG ASSISTS	$5,606
PILOTS	$6,456
STEAMSHIP LINES OR AGENTS	$4,438
MARITIME SERVICES	$157,789
FREIGHT FORWARDERS	$17,351
MARINE CONSTRUCTION/SHIP REPAIR	$221,366
LINE HAUL BARGE/BUNKERING	$31,785
SUBTOTAL	**$1,428,666**
PUBLIC PORT AUTHORITIES	**$37,936**
TOTAL	**$2,242,218**

Source: Martin Associates (2006b)

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